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The new tech set to revolutionize computing **PG. 38**

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STEP-BY-STEP GUIDE

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FIX YOUR GPU

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Digital Edition



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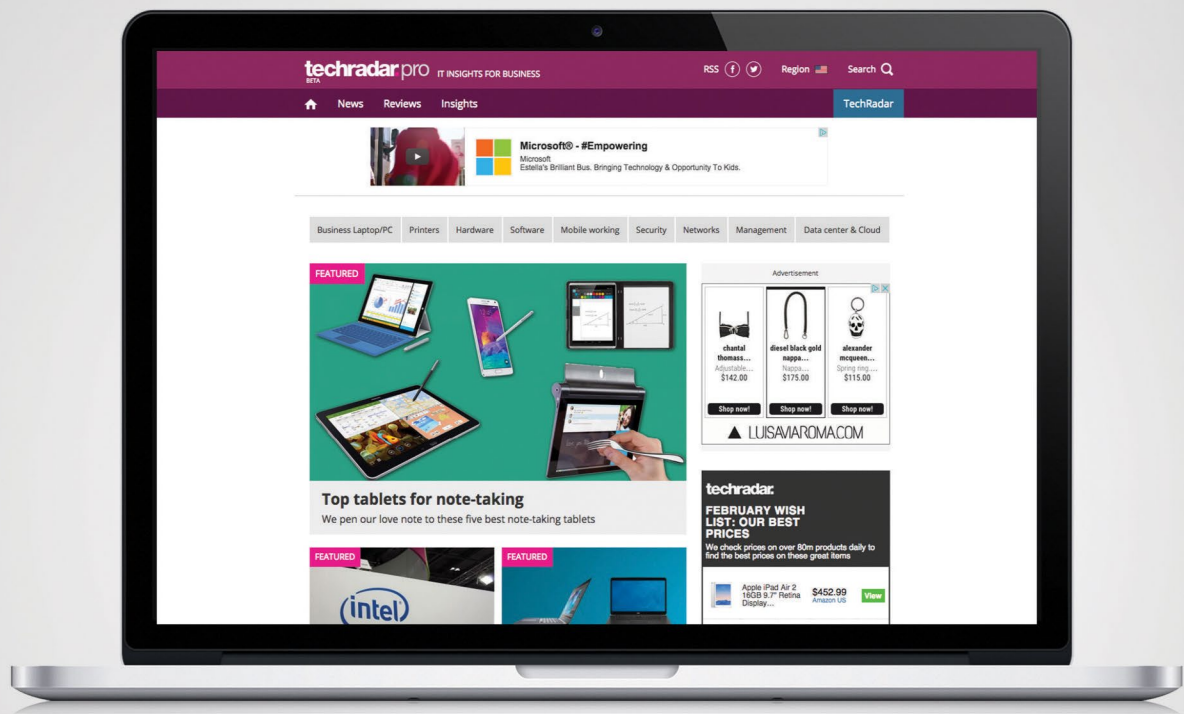
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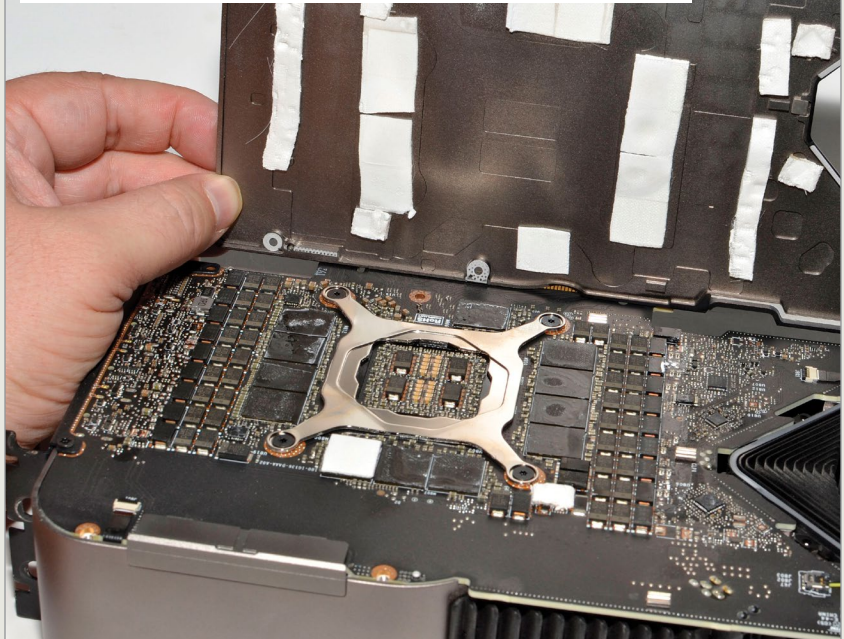
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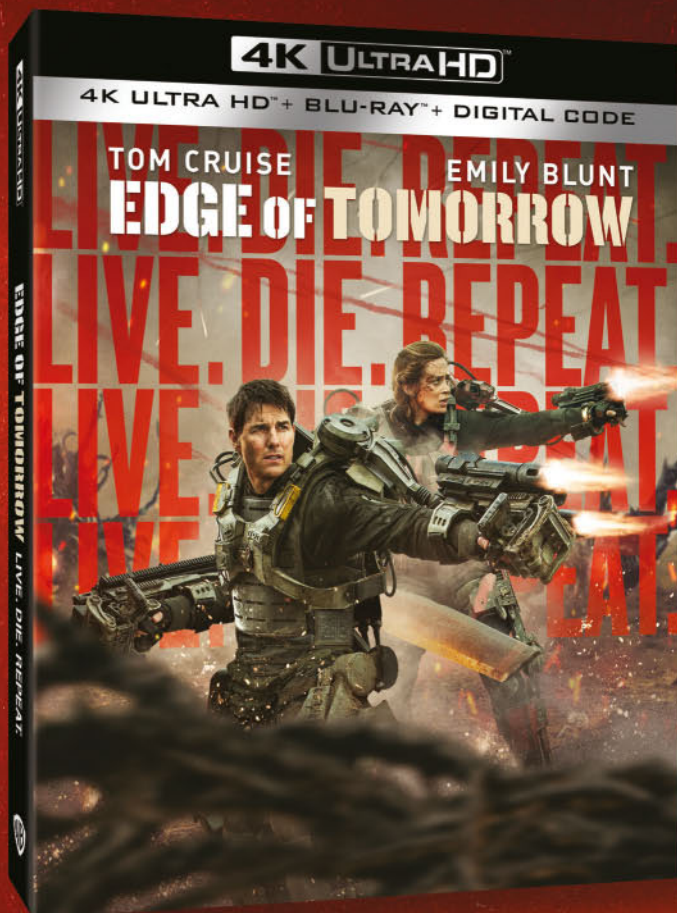
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Guy Cocker

PROJECT ORANGE

WHILE A QUICK GLANCE over past *Maximum PC* covers dispels this myth, desktop PCs still have a reputation for being a little, well, boring. Sure, they come in different sizes, colors, and RGB-lit flavors, but most of the time they're still black (or sometimes white!) monolithic rectangles.

Not so this month's cover build, which is based around Teenage Engineering's computer-1 case. It's orange, as I'm sure you noticed already, with a lovely RAL 2004 powder-coated finish. It also boasts a small footprint and chunky handles to make it easier to carry it from the office to the living room. But its construction is the most interesting element of the design, with 1mm aluminum panels that bend into shape around the internal components in a way I've never seen before.

If the computer-1 looks familiar, it's because we reviewed it in our August 2022 issue. I liked the look of it then, but it was only when I saw it in the (metallic) flesh that I knew we had to feature it on our cover. I'm aware that it might not be for everyone, thanks mainly to its use of a mini-ITX motherboard and the fact that, once assembled, it's not really designed to be opened up again for upgrading. But it's important to highlight the more esoteric side of the PC building scene and what the most creative industrial designers out there are doing to offer something fresh and unique. And it doesn't hurt that the Swedish designers of this case have made something that's begging to be featured on a *Maximum PC* cover. You can read all about it on page 66.

As we barrel towards the end of the year at an alarming speed, talk around the office has turned to the future of the platform and how it might impact our forthcoming issues. For example, I'm keen to do an AMD vs. Intel head-to-head build with Sam, but not if a whole

load of new chips are about to land from either Team Red or Team Blue. To address this, we've got a great feature on the next step in the PC platform—from storage drives to memory, peripherals to display interfaces, everything is getting faster. Starting on page 38, Jeremy Laird looks at what it all means and why we're about to enter a golden age of technical innovation.

We may be on the cusp of a generational leap forward, but in the here and now that means it's a great time to pick up a bargain on current tech, including graphics cards. This month, our GPU guru Jarred Walton looks at what to do if you have a graphics card that needs fixing—maybe you bought it second-hand on eBay and it's more pre-loved than you'd like or you have something lying around that requires some TLC. A lot of people, myself included, might be daunted by the idea of tinkering with a graphics card, but as Jarred shows, it can result in some big drops in memory temps and noise levels. Check it out on page 16.

Elsewhere this issue, we have a feature on a topic I'm often asked about, which is network-attached storage. Nick Peers shows you how to build your own server, not only for secure file storage but also as a media server and a password manager. We also list the 20 most iconic computers of all time. Has your favorite made the cut, and did we miss any out? Let me know at the usual address (editor@maximumpc.com)

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.

submit your questions to: editor@maximumpc.com

THE NEWS

Red vs. Blue

Two new chip families get ready to go head-to-head

THIS FALL we have the pleasure of two new processor architectures landing pretty much simultaneously. First up, Red team. AMD is preparing its 7000-series Raphael chips using the new Zen 4 core architecture and a 5nm process. This is a whole new chip, motherboard, socket, and GPU. We get integrated RDNA 2 graphics, DDR5 memory (no DDR4 support), PCIe 5.0, and a new AM5 socket. There's even a new 6nm I/O chip, replacing the older 12nm example with enhanced low power modes, which is responsible for most of the improved energy efficiency. AI is improved by support for AVX-512 instructions. AMD says it will "try to make a big splash with overclocking" too.

Those Zen 4 cores bring an IPC bump of between eight and ten percent, which are respectable enough, but not as big a jump as earlier generations of Zen. AMD claims more impressive gains elsewhere. Single thread performance gains 15 percent and multi-threaded tasks 35 percent. Overall, it's a performance per watt increase of 25 percent. There's a PPT (Peak Package Power)



Here we go again. Intel and AMD's latest processors are set to meet head-on this fall. Can AMD get back on top again?

of 230W, and a TDP of 170W. This is pretty toasty and should allow you to get a healthy dollop of extra performance under heavy loads. Zen 3 had figures of 142W, and 105W respectively.

AMD is also pushing the clock rates. During Computex 2022, it demonstrated a 16-core 7000-series gaming at 5.5GHz on all cores. AMD claims that Zen 4 features "5.5GHz", so perhaps we'll see even higher boost speeds than that. There will also be a 3D V-Cache version before the year's end, aimed straight at gaming gold. We've no list of actual Zen 4 models yet, but we know the best of the first batch. This is going to be a fast chip and will take back the

crown AMD lost to Alder Lake, but that chip isn't its real rival.

On the other side, we have Intel's Raptor Lake, its first 13th-generation silicon, using the Intel 7 process. This sounds as if it should be 7nm, but is actually a development of the 10nm SuperFin process. Raptor Lake will eventually offer an entire line-up, from entry-level up to a 24-core top model. The basic core architectures remain the same. The performance core gets a new name: Raptor Core. There's more cache, each performance core has 2MB, up from 1.25MB, and each cluster of four efficiency cores now has 4MB rather than 2MB. We also get up to 36MB of L3 cache, for a possible total of 68MB. It will be socket-compatible with Alder Lake, using LGA 1700, and the first compatible boards are already about. Intel promises a "double-digit" performance boost, which is pretty much expected for a new generation these days.

The top dog Raptor Lake, using the full die, will be the Core i9-13900K, with eight performance cores, and 16 efficiency cores. One such example has reportedly been running at up to 5.7GHz, and there have been rumors of even higher clock speeds, with a 5.8GHz or even 6.0GHz boost clock. As with Alder Lake, there's PCIe 5.0 support, and DDR5 memory, with DDR4 support retained. TDP is 125W on the desktop, so not too demanding. Intel also claims it has "enhanced overclocking features", which is intriguing.

The last time AMD had a new core architecture it swept away the competition. Intel's hybrid Alder Lake fixed that and added some useful power efficiency. Raptor Lake isn't as radical an update as Raphael, but it's a solid improvement from a position of superiority. AMD's Zen 4 is a whole new ball game—it not only has to beat Raptor Lake, but also Meteor Lake, which it will be competing against until Zen 5 arrives in two years.

Sides are being drawn online, with fans pointing out the high points of each design. We'll see soon enough for real. Competition between Intel and AMD lit a fire under processor development a few years ago and that is now bearing fruit, with each generation bringing significant improvements. Whichever way this fight goes, it's part of an increasingly productive war that has some time to run yet. **—CL**



Competition between Intel and AMD has lit a fire under processor development.

PCIe VERSION 7.0 BEING PREPARED

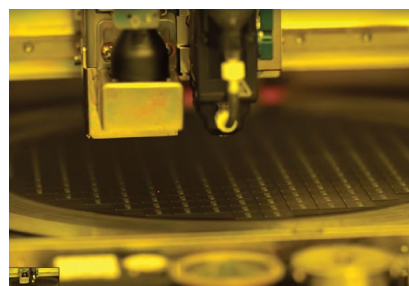


IS YOUR RIG RUNNING PCIe 5.0? Then it's tasty stuff, as version 5.0 is only just about to become properly mainstream. Version 6.0 only recently reached its final specifications, and you won't find hardware around yet. The PCI-SIG (the Special Interest Group that manages the format's standards) has announced that it is "on track" to finalize PCIe 7.0 by 2025. The gap between this and the first hardware being available is just over a year. Each iteration of PCIe doubles the data rate of the previous generation. PCIe 5.0 offers 128GB/s bidirectional transfers on a x16 link, so PCIe 7.0 will take us to 512GB/s. PCIe's impressive bandwidth, right from the original specifications, has given us more than we could ever easily flood with data, which is not something you can say about many interconnect standards. PCI-SIG has kept itself well ahead of the curve, making it king. Expect some PCIe 6.0 kit next year, and version 7.0 stuff in 2026. **-CL**

INTEL 4 THIS YEAR

Team Blue's ambitious plans ahead of schedule

YOU HAVE TO BE impressed with Intel's ambition. It plans to put itself at the top of CPU development by 2025 by producing five nodes in four years. Given the company dropped the ball so often trying to move away from 10nm, we may scoff. But it appears the first step, the Intel 4 process, is now on track for production this year. The Intel 4 process is analogous to 7nm elsewhere and will debut on Meteor Lake chips, which will be 14th-generation CPUs. These are Intel's first tile-based designs and include die-stacking to boot. That's a lot of juicy new Intel technologies in one generation. Reportedly, Intel was to be ready for volume production of the mobile versions before the year's end, but snags with the CPU tile might push that back until next year. Desktop chips will follow, then more die shrinks. Intel's 18A process—that's 18 Angstroms, which is a couple of nodes over Intel 4—is, according to CEO Pat Gelsinger, now six months ahead of schedule, and due in 2024. If all this pans out, this is truly breakneck development. **-CL**



CHIP MARKET COOLS OFF

Companies cutting back on orders

ONE THING the pandemic achieved was to boost demand for consumer electronics. Now though, the economic situation means the propensity to buy new toys has cooled, and that worldwide shortage of silicon barely a year ago has quickly turned around into a glut for many firms.

AMD, Apple, and Nvidia have reportedly asked TSMC to reduce their orders. Nvidia now finds itself holding a good stock of RTX 30-series cards and is having second thoughts about how many 40-series cards it will be able to sell. AMD has revised its 7nm requirements, and Apple has reduced its forecast of iPhone 14 sales down by ten percent. The supply of 5G chips now outstrips demand. Automotive companies that were struggling to get the chips they needed now find they have plenty of stock.

Even the resilient data center market is looking a little fragile. Stock prices have inevitably wobbled, but before we panic, the revenue for most chip manufacturing companies is still growing, albeit gently (Samsung being the exception, partly because of delays with its 4nm process).

You might hope this gives us the prospect of more relaxed pricing, as that's how markets are supposed to work. However, there are reports of trouble brewing further down the supply chain. Japanese company Showa Denko, which supplies materials used in chip production to customers, including chip giants TSMC and Samsung (nearly two-thirds of the world's market), has endured double-digit price increases in raw materials and that is heading down the supply chain.

How much that will hit the bottom line depends on each member of the chain, but Samsung is apparently considering price increases of up to 20 percent. Ouch! If there are bargains to be had, they will be selective and transient. It just shows that markets and events are fickle and near-impossible to predict. **-CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

BIG BOUNTY

Apple is offering a \$2m bounty to anyone who cracks its Lockdown Mode security system.

DIABOLIC SUCCESS

Diablo Immortal may have an unpleasant pay-to-win vibe, but it's still made over \$49 million in its first month.

SMART EYES

Mojo Vision has built a prototype of a smart contact lens, using a minuscule 14,000 pixel LED screen and medical batteries.

TRAGEDIES

GIVE US YOUR DATA

Oculus VR users no longer need a Facebook account but they will need a Meta account and a Horizon World account.

GAME SALES DOWN

The US video game market is predicted to contract to \$55.5bn this year, down nine percent.

APPLE HITS META

Apple's latest privacy policy, which allows you to stop apps tracking your activities, will cost Meta \$10bn in lost revenue.



RDNA3 VS. ADA LOVELACE

Next generation graphics cards square-off

AFTER A HORRIBLE couple of years, the graphics card market has finally settled down. Supplies and prices are nearly back to normal and demand from the crypto mining farms has eased. Even better is the prospect of the next generation of GPU architectures from AMD, and Nvidia this fall. If you've delayed upgrading your rig, you will soon have some decent options.

From AMD, we have the RDNA 3 architecture featuring AMD's chiplet design rendered in 5nm silicon. The Compute unit has been 'rearchitected', which, we hope, means extra compute pipelines. We also get a "new generation" Infinity cache, with a 384-bit bus on the cards. According to AMD, RDNA3 will offer a 50 percent increase in performance per watt over version 2. The first 7000-series cards will use Navi 31 and 33 GPUs, with the mid-range Navi 32 to follow.

Over at Nvidia, we have the new Navi GPUs, codenamed Ada Lovelace (after the pioneering computer programmer). These use TSMC's N4P process, a modified version of its 5nm process. Nvidia is expected to start its 4000-series cards at the top, including an RTX 4090 with an AD102 GPU and a 50 percent faster boost clock speed than the RTX 3090. That's on top of a new architecture design and more cores, meaning the green team can match AMD's generational performance gains.

Both GPUs' architectures are expected to be power hungry: the top-tier cards will have consumption figures of up to 450W (if rumors are to be believed, even more). It gets worse, as AMD released a graph of expected power consumption by GPUs which featured a 700W chip in 2023. This is going to stretch the standards of the ATX3.0 power supply, if true. Power consumption aside, the graphics card market is about to, metaphorically speaking, step from the gloom into the sunlight again. **-CL**

Threadripper goes all Pro

AMD'S THREADRIPPER CHIPS were something of an outsider, sitting between the world of consumer HEDTs and business workstations. AMD markets these 64-core Goliaths as the world's most powerful desktop processors. The latest 5000-series gains Zen 3 cores. There are three of them: the 64-core Ryzen Threadripper Pro 5995WX, the 32-core 5975WX, and the 24-core 5965WX. AMD has decided to make all Threadrippers 'Pro', so you get security features you may not need on a desktop.

Someone has already liquid-cooled an engineering sample of the Threadripper 5990X, overclocked it, and destroyed Cinebench R23 benchmarks at over 100,000 points. The downside? Threadrippers run from \$2,399 all the way to \$6,499. This pricing, and the dropping of all non-Pro versions, are further indications that AMD has quietly moved the Threadripper into the professional domain.

Originally, Threadrippers were marketed as the extreme desktop chip, and AMD managed to push Intel off the top spot for HEDT hardware. Here was a 16-core desktop chip that sat neatly between the 8-core Ryzen desktop chips and the 32-core EYPCs, which were strictly server stuff. Then the 3000-series came along with proper Pro versions and more memory channels, and it straddled the markets. These 5000-series versions are desktop chips for only the most dedicated, really being Xeon rivals. It's the end of an era, but AMD's desktop chips are now multi-core monsters in their own right and don't need a HEDT halo model. Plus the HEDT market has pretty much disappeared and Intel hardly bothers with it these days. **-CL**



The HEDT market loses its brightest star; Threadripper has put on a suit, and gone professional.

Apple's Hot Books

The new M2 chip made its debut in the MacBook Pro in mid-July, and early tests found its cooling is struggling to cope. The 13-inch M2 MacBook Pro has a single fan and, under extended load, the M2 chip can reach over 100 degrees, triggering thermal throttling. This saves your silicon but leaves you with a sluggish rig. The 13-inch M1-powered MacBook Pro gets toasty under similar loads, but at least avoids being held back. Some were also disappointed by the slower SSD speeds. The base model has a single SSD chip, rather than the predecessor's two, pushing you to spend another \$200 for the two-chip 512MB version or lose half your data transfer speed. Let's see if the M2-powered Macbook Air, with no fan, can keep its chip cool. **-CL**

Samsung goes 3nm

Samsung has beaten arch-rival TSMC to the 3nm chip and is starting limited production for a Chinese crypto mining accelerator. The headline isn't the 3nm metric, but rather that Samsung has shifted from FinFET to GAA transistors, the first to do so. GAA stands for Gate-All-Around, which employs nanosheets, and these are a way to construct the transistor gates. Samsung claims a 45 percent reduction in power consumption, and up to a 23 percent speed hike over 5nm chips. Making a new process node is about transistor density, rather than some nominal measurement that you would be hard pressed to identify on the silicon. This would make a more informative and descriptive metric, so can we please start using this instead? **-CL**



Jarred Walton

TECH TALK

AMD Kills Off Non-Pro Threadripper

HEDT (HIGH-END DESKTOP) platforms once reigned as the fastest CPUs available, targeting enthusiasts who wanted more. Intel created the HEDT space with socket LGA1366 in November 2008, and for a while the Core i7-920 was one of the best enthusiast processors. It was the first consumer four-core/eight-thread CPU, running at 2.66GHz base and 2.8GHz boost.

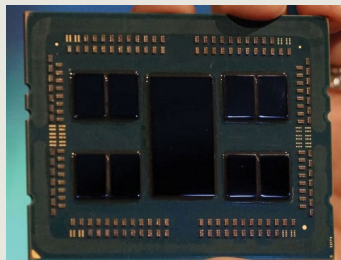
The thing is, you could crank the voltage up a bit and set the BCLK to 190/191MHz and suddenly you had a chip running at 4GHz.

From 2009 until 2017, Intel didn't bother selling mainstream desktop CPUs with more than four cores to the masses. If you wanted something better, you had to move up to HEDT. There were six-core Gulftown CPUs in 2010, Sandy Bridge-E and Ivy Bridge-E stayed with six cores but moved to quad-channel DDR3 memory controllers, and Haswell-E increased the core count to eight in 2014, swapping to DDR4 at the same time. Broadwell-E and the Core i7-6950X topped out at ten cores and 20 threads for a staggering \$1,723 in 2016.

AMD was nowhere to be found in the HEDT space, with the languishing Bulldozer derivatives trailing Intel CPUs that were several years old. And then Ryzen happened. Suddenly AMD was part of the enthusiast CPU story again, offering eight-core/16-thread CPUs at competitive prices. The Ryzen 7 1700 was a \$330 CPU that blew past the Core i7-7700K in multi-threaded workloads, all for a lower price, and Intel finally had to move beyond four-core CPUs on its mainstream LGA115x platform.

But AMD didn't just attack the HEDT space with consumer parts; Threadripper was a full-scale assault on Intel's priciest CPUs. Threadripper 1950X gave people 16 cores for \$1,000, eclipsing Intel's top solution. The response with Skylake-E and chips such as the Core i9-9980XE might have partially reclaimed the crown for thread counts, but at a much higher power draw. Then AMD doubled down with the second-generation Threadripper 2990WX offering up to 32 cores and 64 threads. It was a blowout of, well, EPYC proportions.

In early 2020, AMD truly put the nail in the Intel HEDT coffin with a 64-core Zen 2-based



The Threadripper Pro 5000WX line is the same as the EPYC workstation line now, but without dual sockets.

Threadripper 3990X. Granted, at that point we'd moved well past what even serious enthusiasts might consider buying, as Threadripper 3990X cost a cheeky \$3,990 at launch. Intel didn't have anything that could compete with AMD's multi-threaded monsters.

But that's the end of the line for regular Threadripper, as AMD now wants to merge HEDT with its Threadripper Pro offerings. Make no mistake, Threadripper Pro is a beast, with an eight-channel memory controller and 128 PCIe lanes. Vanilla Threadripper 'only' offered up to 72 PCIe lanes and four-channel memory support. But the extra lanes and memory channels come at a cost, literally.

There will be no Zen 3-based Threadripper CPUs, just Threadripper Pro and the WRX80

chipset and platform. Threadripper 3990X was already expensive at four grand, but its replacement, Threadripper Pro 5995WX, has the same 64-core/128-thread count and will cost \$6,499. Similarly, the 32-core Threadripper 3970X that cost \$1,999 has been replaced by the 32-core Threadripper Pro 5975WX at \$3,299. And it's not just pricier CPUs; the motherboards cost more, and you have to populate eight memory slots instead of four.

At least for the time being, AMD is content to serve the consumer market with products like Ryzen 9 5950X, which mostly kills off the need for Threadripper anyway. HEDT merges into the workstation market, but it's less a merger and more the death of HEDT as an option. Perhaps Intel will try to revive HEDT, but with Core i9-12900K offering 24 cores and 32 threads, and the Raptor Lake chips ready to deliver 32 cores and 40 threads in the near future, the writing is on the wall. Moving to dual-channel DDR5-6400 should also mitigate bottlenecks from dual-channel memory controllers.

So, farewell HEDT. It was a good run while it lasted.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

TOP FIVE GAMING LAPTOPS

GAMING LAPTOPS are a contentious issue here at *Maximum PC*, with some of our writers loving them and others loathing them. Regardless, they remain a common entry point to PC ownership for many, thanks to their versatility, portability, and generally high-power performance. These are the best gaming laptops out there right now across a range of sizes, styles, and budgets, so you can get your game on no matter where you are or what you're doing.

5

HP VICTUS

If you're looking for a good value gaming laptop, HP's Victus line is a good place to start. They still feature luxuries such as a 16-inch display, but save money with modest specs that still pack a punch, such as a Ryzen 7 processor, RTX 3050 Ti GPU, and 16GB of RAM. They also look particularly sleek too, which is to say they look nothing like most gaming laptops. **\$950, www.hp.com**

4

ACER PREDATOR HELIOS 300

With its \$1,500 sticker price, the 15-inch Predator Helios 300 provides high-end 1080p gaming at a mid-range price. It combines everything most gamers need, with an RTX 3060 GPU, Intel 12th-gen CPU, and 144Hz screen. It's also relatively thin and light, and has a one-touch overclocking feature for when you need maximum performance. **\$1,500, www.acer.com**



3

ASUS ROG ZEPHYRUS G14

If you want a gaming laptop without all the bulk that implies, the ROG Zephyrus G14 is the compact and lightweight model to go for. That doesn't mean it skimps on features, though, as it includes a large 16:10 aspect ratio screen, 120Hz refresh rate, and a beastly AMD Ryzen 6900HS processor. In fact, it's an all-AMD machine, thanks to the RX 6800S or RX 6700S GPU options. **\$1,599, www.asus.com**



2

RAZER BLADE 15/17

Razer's gaming laptops are still the sleekest around, thanks to their gorgeous CNC-milled aluminum chassis and lightweight 5lb body (on the 15-inch model, at least). The newest models rock Intel's 12th Gen processors, although it could be worth looking at the 11th Gen models if you find them on sale. That's because the one thing Razer laptops aren't is cheap. **\$2,499/\$2,799, www.razer.com**

1

LENOVO LEGION 5/5I PRO

Simply the best gaming laptop for most people, Lenovo's machine perfectly balances power, features, and price. The main attraction is the huge 16-inch 16:10 165Hz G-Sync display, which is fantastic for gaming and work, while also fitting into a 15-inch chassis. It also has four-zone RGB lighting and superior internal cooling, and it's dead easy to upgrade RAM and storage. **\$1,999, www.lenovo.com**





Jeremy Laird

TRADE CHAT

Intel's PC platform problem

YOU CAN READ ELSEWHERE in this issue about the future of the PC platform—the bottom line is an increase in bandwidth across the board. But the PC platform is not monolithic, instead, it's bifurcated between Intel and AMD. And increasingly, it looks like AMD will have an advantage for some time.

The issue involves PCIe connectivity, specifically PCIe connectivity for M.2 SSDs. As explained in the platform feature (see page 38), Intel made it first to market with PCI Express 5.0 support with 12th Gen Alder Lake CPUs and the 600 series chipset. The catch is that it's limited to 16 lanes, which means no native PCIe 5.0 for M.2 storage slots, with add-in cards required for most 600 series motherboards to support PCIe 5.0 SSDs.

There are a few exceptions. In other words, there are Intel Z690-based motherboards with native PCIe 5.0 M.2 slots. The catch is that to use them, you have to pinch lanes from the PEG-16 slot, cutting the bandwidth available to the graphics card in half. One can argue whether that matters for existing GPUs. But the chances of performance being compromised will only go up when new GPU tech arrives later this year and thereafter.

Notably, AMD is promising that the new AM5 socket and Ryzen 7000 CPUs will have sufficient PCIe 5.0 lanes to support both full 16-lane graphics links and native M.2 storage in parallel. Advantage AMD? Yes, and that doesn't look likely to change any time soon. For starters, Intel's next platform for 13th Gen Raptor Lake CPUs carries over exactly the same chipset hardware and PCIe connectivity. Making matters worse, the latest news on Meteor Lake, the 14th Gen CPU family that follows Raptor Lake, is they have been pushed out to the end of 2023 at the earliest thanks to problems with Intel's new 7nm production process, branded Intel 4.



It's not all bad news for Intel. But clearly, the PC's biggest beast isn't yet back on track.

In fact, there are rumors that Intel 4 is proving so problematic that Intel may have to go begging to Taiwanese foundry TSMC to help with Meteor Lake CPU core chiplet production (TSMC has already been booked to produce Meteor Lake's integrated graphics chiplet). So even if Meteor does bridge the PCIe 5.0 gap, it looks likely that AMD will have the market to itself for at least 18 months when it comes to what you might call a proper PCIe 5.0 storage solution. OK, actual PCIe 5.0 SSDs remain the stuff of marketing slides, but a year from now they will be widely available and cranking out as much as 14GB/s on AM5 motherboards.

In other words, when you add in Intel's apparent troubles with its new Arc graphics cards, which are now long overdue and look set to disappoint in performance terms, it's hard not to conclude that Intel's woes continue. That's despite firm assurances from CEO, Pat Gelsinger, that Intel would rapidly get its core competence of chip production running smoothly.

It's a pity, because Intel may actually have the best CPU in the next round. All the indications are that AMD's Zen 4 microarchitecture and the Ryzen 7000 CPU family is going to be a minor die-shrink rather than a radical leap forward. With a limited IPC increase, a small



The Raptor Lake CPU may not have native PCIe 5.0 M.2 storage support.

clockspeed bump, and no additional cores, it's not going to be a radical step in terms of performance.

Meanwhile, Intel is giving its upcoming Raptor Lake CPUs an additional eight efficiency cores along with extra single-threaded performance to an architecture that already has the best IPC on the market. I expect Raptor Lake to have the edge for both single and multi-threaded performance.

So, it's not all bad news for Intel. But clearly, the PC's biggest beast hasn't entirely got things back on track. If Intel can't get its Intel 4 process technology under control, its long-term prospects will become a genuine worry.

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> Quick Privacy Tips

> A New Browser

> PortableApps

Tighten Privacy

In the July issue, you had a news article titled “FBI Searches Data Without Warrants”. They aren’t just spying on people, they act on it, too. Thousands of arrests are made every year due to the FBI or other alphabet-soup government agencies invading our privacy. Hacking and ransomware attacks are at an all-time high.

My suggestion to you is to have a full feature on privacy and how to keep your data secure. I believe Nick Peers has done this before, maybe a few years ago now, but he did a great job. It could cover how simple it is to have your data monitored (or stolen) if you’re not being careful, and how to prevent it from happening by using VPNs, TOR, encryption, and any relevant Linux distros.

This is such an important issue, it should be covered annually to keep everybody up to date with what is out there to keep data secure and your privacy intact.

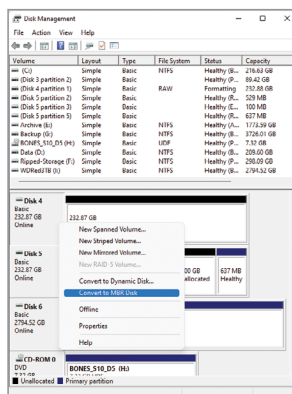
—Dillon Kenneth Wicks

THE DOCTOR RESPONDS: The Doc has it on good authority that such a feature will be incoming at some point in the near future. In the meantime,

here’s some quick advice on what tools can—and can’t—do to protect your security and privacy.

First, make sure you have strong up-to-date anti-malware software to keep malware (including spyware and hacker tools) off your PC. Ensure your entire network—including your router—is protected. In the case of your router, disable any remote administration options and change the default password if you haven’t already. Also, check your router’s firewall is enabled and that UPnP is disabled to prevent drive-by hackers from discovering a backdoor to your system. Finally, you should visit <https://routersecurity.org/testrouter.php> to perform a series of tests to verify how secure you are.

That deals with inbound threats, but how do you protect your own legitimate excursions onto the internet? Your first line of defense should be a VPN—this not only scrambles your data across wireless networks (secure or otherwise), but it also masks your internet activity from your own ISP as well as your true location from any servers or sites you



Initialize SSDs as MBR for use with your TV.

communicate with. Choose a VPN headquartered outside the 14 Eyes surveillance network—see www.techradar.com/vpn/best-free-vpn for a list of the best free ones to try.

Note that VPNs mask your data during transit from your ISP to the VPN’s own server, but from that point on it’s decrypted and visible—you still leave a footprint. In terms of encrypting your actual internet traffic, you need to make use of additional tools, from a browser such as Tor (www.torproject.org), which scrambles all your data to help evade trackers, to a trusted end-

to-end encrypted messaging application, such as Signal (<https://signal.org>). You shouldn’t even trust your cloud storage provider’s own encryption tools to keep your data safe—wrap data in another encrypted layer such as that offered by Cryptomator (<https://cryptomator.org>), so even if your cloud provider hands over your encryption keys to the authorities, they’d still only find scrambled data awaiting them.

As well as wrapping yourself in multiple layers, consider what activity you do perform on the internet. You should assume you’re still being monitored and act accordingly.

Niche Browser Tip

Browsers come up regularly in the mag, and from time to time there’s a head-to-head comparison of popular ones. I’m wondering what you guys think about my browser of choice: Brave. Tor is built-in, there’s a rewards system that allows you to earn crypto as you browse, ads are blocked by default, and more. It’s fast and reliable, based on the open-source Chromium browser from Google. I like

submit your questions to: doctor@maximumpc.com

it more than any browser I've tried in the past, and don't plan on switching anytime soon. It's not as popular as the big dogs but has a devout following. I'm interested in what you guys think about it.

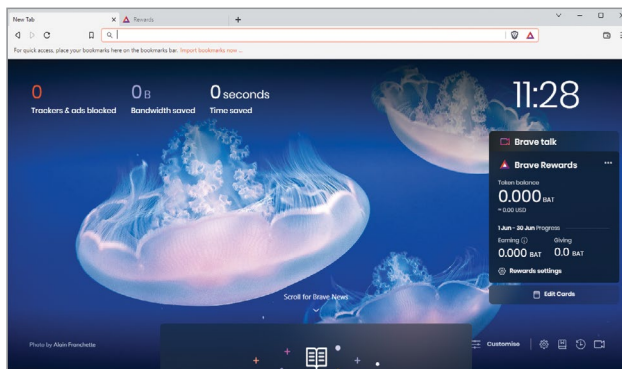
—Mark Lonnemann

THE DOCTOR RESPONDS:

There are dozens of browsers, all aimed at different markets and niches, but when it comes down to it, you're basically choosing between variations on three browser engines. The majority—including Brave—are powered by Google's Blink, while Firefox (and variants, such as Waterfox) continues to plow its own furrow with its open-source Gecko engine. The third option—WebKit—is Apple's entry into the market (little-known fact: Google's Blink developed as a fork from WebKit).

The Doc has all major browsers installed on his PC for one reason or another but defaults to Firefox. Blame his obsession with supporting the 'little guy'. The downside is that not all sites work well with Gecko, so as a backup he usually reverts to Edge, Opera (when wanting a quick-and-dirty VPN), or Vivaldi (because it's just so damn configurable).

While *Maximum PC* has yet to cast its discerning eye over Brave, it's clear you've done your homework, and if the browser does what you need, there's no reason to care what we think. That said, if you do want additional validation, our sister title *Linux Format* awarded Brave 9/10 back in January 2021. That's some accolade, given it was written by tech guru and self-confessed "Firefox loyalist" Jonni Bidwell, who concluded: "Brave really is a better browser, even if you don't care about its rewards program. Well worth your basic attention." This verdict was backed up by Shashank Sharma, who later placed Brave top of the list in *LXF's* web browser roundup, beating the likes of Opera



Brave is a privacy-focused browser with crypto rewards.

and Vivaldi across a range of metrics, including ease of use, privacy, security, and performance.

Long story short: Your recommendation, backed up by *Linux Format*, means the Doc is going to add another Chromium-based browser to his installed list. Maybe it's time Edge got bumped for something a little Brave(r)?

SSD Not Detected

I was intrigued by your suggestion of hooking up a Samsung T5 ultra-portable SSD to my TV in place of a flash drive to record TV shows. Unfortunately, I can't get my TV to recognize the drive, despite having formatted it as FAT32 as per the TV manual's instructions. Am I missing something obvious?

—Georges Galindo

THE DOCTOR RESPONDS:

The Doc missed out on one key bit of information when recommending SSD drives for TVs—you may need to reconfigure the drive to use the MBR partition table instead of the default GPT. Note that MBR-partitioned drives can only access the first 2TB on any drive, but as T5 drives currently max out at 2TB, that won't be a problem.

You can reinitialize the drive in Windows—this is a completely destructive process, so if there's any data on the drive, copy it off first. Then open Disk Management (press Win+R, type "diskmgmt.msc" and hit Enter). Locate your T5 drive,

right-click any volumes set up on it, and delete the lot to leave only "unallocated" space. Now right-click to the left of the unallocated space (namely where it says "Disk 'x', Basic) and choose "Convert to MBR Disk."

You don't get confirmation this has happened, so right-click again and choose "Properties → Volumes tab" to verify the partition style is set to "Master Boot Record (MBR)." Click "OK," right-click inside "Unallocated," and choose "New Simple Volume," then follow the prompts to initialize the disk, making sure "File system" is set to FAT32 or one that's compatible with your TV.

Once done, you should be able to plug the drive into your TV and use it both to record and play video.

PortableApps Glitch

I use PortableApps.com to run as many apps as possible without installing them on my hard drive. I love the way it works with most portable apps, not just those you can install through the platform.

However, I've run into a problem: While I can copy most program folders into the "PortableApps" folder, then click "Apps → Refresh App Icons" to get them to pop up in the PortableApps launcher, some apps don't appear. I've discovered these are app executables stored inside subfolders within their own parent folder. Is there a way to get PortableApps to recognize these programs,

too, so that I can file them into the main launcher?

—Frederick P Legault

THE DOCTOR RESPONDS:

It's rare for this problem to occur—if you install CCleaner Portable manually (see www.ccleaner.com/ccleaner/builds), for example, you'll run into this issue. Luckily, there is a fix but it's a convoluted one.

First, browse to the CCleaner folder and create a subfolder inside called "app". Open this and create a further subfolder called "appinfo". Finally, navigate into this folder, right-click and choose "New → Text Document" to create a blank text file in your text editor.

Type the following lines:

```
[Format]
Type=PortableApps.
comFormat
Version=0.9.8
```

```
[Details]
Name=CCleaner
Publisher=Piriform
Homepage=ccleaner.com
Category=Cleanup
Description=CCleaner
```

```
[Version]
PackageVersion=6.00.9727
DisplayVersion=6.00
```

```
[Control]
Icons=1
Start=\x64\CCleaner64.exe
ExtractIcon=\x64\
CCleaner64.exe
```

Fill in the [Details], [Version], and [Control] tabs with information from your portable app—when using [Control] to specify the app location (Start=) and its icon (ExtractIcon=), your app's parent folder is considered the 'root', so make all paths relative to this.

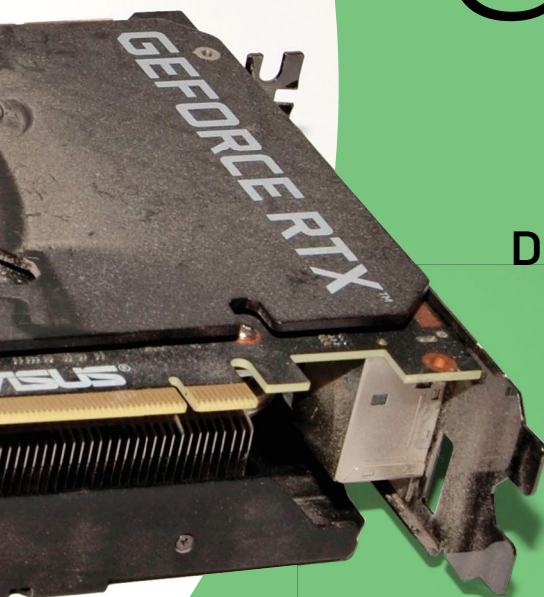
Save the file as "appinfo.ini" (make sure it has the .ini file extension, not .txt). Then reload the PortableApps launcher and you should see your app under your chosen category, with the correct icon and details. Click it to verify it launches; if anything is amiss, reopen "appinfo.ini" to review your edits. ☺



These two RTX 3090 cards, an Asus TUF Gaming and a Founders Edition, were running side by side in a mining rig and apparently hadn't been cleaned in quite some time.

BREATHE NEW LIFE INTO AN ABUSED GRAPHICS CARD

Drop your GDDR6X temps and noise levels



As we again reach the point where cryptocurrency mining using GPUs stops delivering an acceptable return on investment, a deluge of used graphics cards is landing on the second-hand market. Depending on the card and the miner, some of these might be in great shape; others might be covered in dust and run at higher temperatures than normal, leading to reduced performance.

Or perhaps you're simply the owner of a card that's been kicking around for a couple of years. If you've had it in your PC for a while and haven't bothered to give it a thorough clean, it might be running hotter and louder than when it was new.

Whatever the source, any used graphics card can benefit from routine maintenance. More importantly, Nvidia's RTX 30-series cards that come equipped with GDDR6X memory often run it at uncomfortably high temperatures, hitting 100°C or more even when gaming—and reaching 110°C and throttling performance when mining Ethereum and other memory-intensive coins.

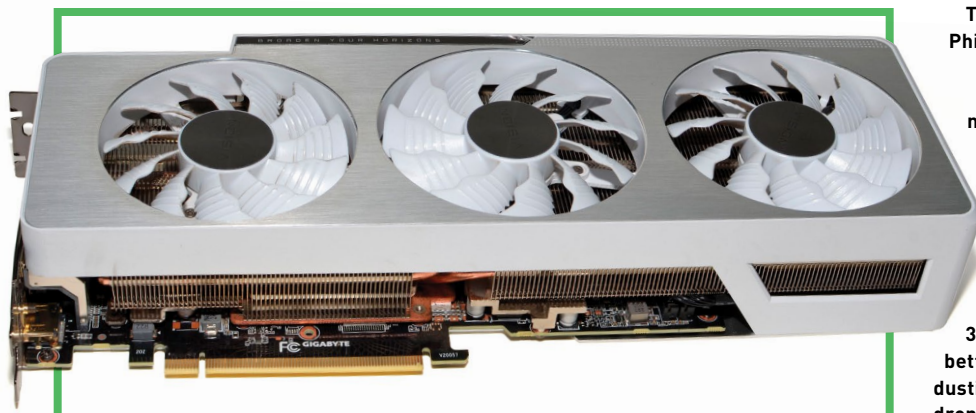
We've managed to get our hands on some used RTX 30-series cards that have been used for mining, and we've checked performance and thermals before and after replacing the thermal pads and thermal paste. The improvements on every card were substantial and well worth considering if you have a graphics card that's running on the toasty side. —JARRED WALTON



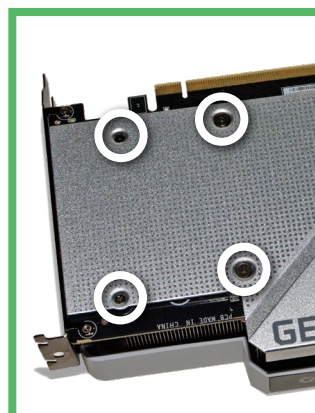
This Gigabyte card spent 15 months in the crypto mines and was in dire need of some TLC.



There were only 10 Phillips head screws holding this card together, which made disassembly simple compared with some of the other cards.



The Gigabyte 3080 already looks better with some dusting. Fan speeds dropped quite a bit too.



START WITH A THOROUGH CLEAN

We apologize if some of the images you'll see here offend your eyes. We love fast hardware, and we know that routine maintenance of our PCs is important to keep everything running smoothly. Not everyone knows how to care for their PC hardware, though, whether mining or gaming, just as not everyone takes proper care of their automobile. It doesn't help that there's no "Check Engine" light that kicks on every few months to remind you that it's a good time to dust out your PC.

A friend, who shall remain nameless, started mining cryptocurrencies in late 2020 and managed to acquire a variety of cards over the past 18 months. We're not here to judge (very much), but the opportunity to test and service some of the cards was too good to pass up. After looking at the small mining farm, we selected four of the worst-performing

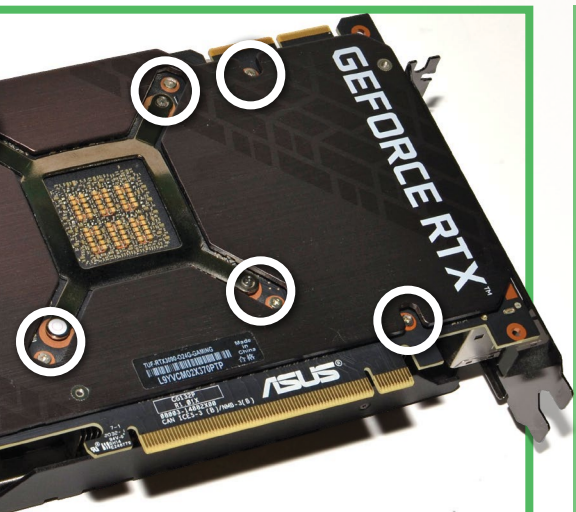
GPUs to see what sort of gains could be had via a proper clean and refurbishment of the cooling hardware. We chose two RTX 3080 cards and two RTX 3090 models: a Founders Edition for each GPU, then a Gigabyte Vision, and an Asus TUF Gaming.

All four GPUs were, as our friend put it, "underperforming" when it came to Ethereum mining, and the cause was obvious. Memory temperatures were at 110°C, typically the maximum you'll see from Nvidia's Ampere GPUs with GDDR6X memory before severe throttling kicks in. Some of the cards were only at 92–96°C on their memory, even while delivering better mining performance. Those four "problem children" had never quite reached their potential, but they were still fast enough that it wasn't really a concern, at least not until mining profitability started to plummet. Given the amount of dust on the cards and fans,

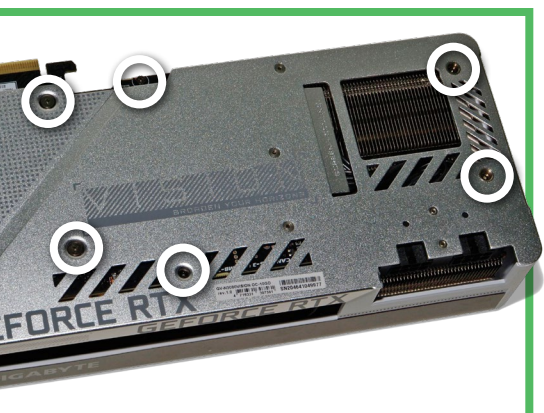
that's where we started. While in theory, all you need is a strong current of air to blow out the dust, compressed air is the safest option. We've heard of some people who use air compressors, but those can add moisture—a definite no-no for electronics. Others might use a Shop-Vac with a small nozzle, but those can cause electrostatic discharge, especially in dry climates. Depending on the amount of dust, a single can of compressed air might clean two or three cards, which is better than ending up with a broken graphics card that's still worth hundreds of dollars.

PREPARE FOR DISMANTLING

Virtually every graphics card has a different disassembly process. Your best option before beginning is to try searching for the exact card model with "disassembly" and see if you can find a YouTube video that walks through the



The Asus 3090 TUF Gaming had 14 screws on the back and another five on the other side holding it together.



process. Even if you can't find a video, the procedure is usually straightforward, but you'll want to take it slow and verify that you didn't miss anything holding the card together before you attempt to pry off the heatsink or backplate.

Nvidia's Founders Edition cards are well documented, with hidden screws underneath some covers that can be pried off. The Asus card was the most difficult to disassemble, mostly because it had a separate dedicated heatsink for cooling half of the memory—how that was necessary when the GDDR6X on the back of the PCB (printed circuit board) only got a metal backplate remains a bit of a mystery. The Gigabyte Vision was the easiest to take apart because all the screws were accessible from the back of the card, and it only had 10 screws holding everything together. Besides screws, you also need to pay attention

CHOOSE A GOOD THERMAL PAD

Every graphics card model is different, and most manufacturers seem to use less than stellar thermal pads. While that might have been OK with GDDR5 memory, or even standard GDDR6, GDDR6X uses more power and can create substantially more heat to dissipate. Even if you're not mining, you should seriously consider putting in better thermal pads.

Thermal pads come in a variety of thicknesses, from 0.5mm up to 2.0mm, maybe even higher. Most cards seem to use 1.5mm or 2.0mm pads, and we were able to use 1.5mm on all the cards we tested. Still, if your card only needs 1.0mm pads and you try something thicker, you can end up with a larger gap between your heatsink and the GPU. That can result in

extreme GPU core temps and a locked-up PC—not that we experienced anything like that when testing [whistles innocently...]

Besides the pad thickness, the most critical aspect is the thermal conductivity of the pad. This is normally given in W/mK (watts per meter Kelvin), and higher numbers are better. We used some Thermaltake Extreme Odyssey pads rated at 12.8W/mK, and while we don't know the original conductivity of the pads we replaced, we suspect most were rated at less than 6W/mK.

You could also use copper shims, with a good thermal paste on each side. The thickness of the shim is far more important than with a pad because there's no



Nvidia's RTX 30-series Founders Edition cards with GDDR6X VRAM are notorious for their poor memory temperatures, and the culprit is garbage thermal pads that simply don't conduct heat very well.

give with copper. Copper shims are also rated at around 400W/mK. Yeah, that's far better than any thermal compound. You'll probably want some thermal pads to fill in the areas around the copper shims, though, because, unlike the pads, copper can conduct electricity and potentially short out your GPU if you're not careful.

to cables for the fans and lighting. Most third-party cards have longer cables that are pretty obvious, but the Founders Edition has three small connectors (two for the fans, one for lighting) that you might miss at first glance. If you happen to rip out a cable, you could very quickly end up with a dead graphics card—or at least a card that needs a Frankenstein fan configuration to keep it cool.

Don't just start removing screws, but first create a clear workspace where you can keep track of where every screw goes—taking pictures as you go is also helpful when it comes time to reverse the process. You should also have a variety of tools at hand. The most common tool is a screwdriver, but you probably need multiple different tips. We have two small Husky screwdrivers that we purchased ages ago that have served us well. Each has four reversible heads of different

sizes, so 16 tips in total. One has Phillips head tips on one side and flat head tips on the other, with sizes ranging from small to minuscule. The other screwdriver has Torx bits, with sizes from T-4 up to T-10, plus T-15. Having a small plastic prybar can also be handy, and when it comes time to get rid of the old thermal pads, a wider flat plastic tip makes things far less messy. You might also need a pair of tweezers, which are definitely useful on the Founders Edition cards. Get some cleaning options such as Q-tips and pure isopropyl alcohol as well, and a good light for the work area.

CRACK THE CASE

Tools in hand, it's time to start taking the card apart. Find the right screwdriver tip as needed, and it's good to partially loosen all screws and then proceed in an "X" pattern—both when removing and

CHECK YOUR VRAM TEMPERATURES

There are a few utilities you can use to find your graphics card memory temperature, and the easiest is HWInfo64. Download the latest version and run it in “Sensors only” mode. Scroll to the graphics card section near the bottom, and look for “GPU Memory Junction Temperature.” At idle, most cards are in the 40°C range, give or take, but gaming and especially cryptocurrency mining put a heavy load on the memory and reach much higher temperatures.

If you want to find the worst-case scenario, Ethereum mining generally does the trick. Download NiceHash QuickMiner and let it run for a few minutes—you may need to set up an account first, but don’t worry about the few cents in cryptocurrency you might lose by mining with someone else’s account. We’re just here for the stress testing.

You can also skip HWInfo64 and QuickMiner, and instead use NBMiner. That’s also an option using the more fully featured NiceHash Miner software, which auto-switches to the most profitable cryptocurrency based

Sensor	Current	Minimum	Maximum	Average
GPU (#1): NVIDIA GeForce RTX 3090				
GPU Temperature	60.8 °C	60.7 °C	61.2 °C	60.9 °C
GPU Memory Junction Temperature	92.0 °C	92.0 °C	92.0 °C	92.0 °C
GPU Hot Spot Temperature	73.0 °C	72.8 °C	73.6 °C	73.1 °C
GPU Core Voltage	0.775 V	0.756 V	0.819 V	0.788 V
GPU Rail Voltages		0.813 V	11.997 V	
GPU Fan1	1,829 RPM	1,825 RPM	1,884 RPM	1,844 RPM
GPU Fan2	1,829 RPM	1,828 RPM	1,880 RPM	1,844 RPM
GPU Power	279.107 W	276.026 W	280.166 W	279.636 W
GPU Rail Powers		7.605 W	170.677 W	
GPU Clock	1,125.0 MHz	1,005.0 MHz	1,230.0 MHz	1,150.8 MHz
GPU Memory Clock	2,563.0 MHz	2,563.0 MHz	2,563.0 MHz	2,563.0 MHz
GPU Video Clock	1,380.0 MHz	1,380.0 MHz	1,380.0 MHz	1,380.0 MHz
GPU Effective Clock	1,169.0 MHz	1,130.0 MHz	1,302.3 MHz	1,162.9 MHz
GPU Core Load	100.0 %	100.0 %	100.0 %	100.0 %
GPU Memory Controller Load	100.0 %	100.0 %	100.0 %	100.0 %
GPU Video Engine Load	0.0 %	0.0 %	0.0 %	0.0 %
GPU Bus Load	0.0 %	0.0 %	2.0 %	0.1 %
GPU Memory Usage	50.5 %	49.7 %	50.5 %	49.8 %
GPU D3D Usages		0.0 %	100.0 %	
GPU Fan1	70 %	70 %	72 %	71 %
GPU Fan2	70 %	70 %	72 %	71 %
GPU Performance Limiters	Yes	No	Yes	Yes
Total GPU Power (normalized) [% of TDP]	85.9 %	79.4 %	88.0 %	85.3 %
Total GPU Power [% of TDP]	79.5 %	73.8 %	81.6 %	79.8 %
GPU Memory Allocated	12,399 MB	12,212 MB	12,399 MB	12,243 MB
GPU D3D Memory Dedicated	12,181 MB	11,994 MB	12,181 MB	12,025 MB
GPU D3D Memory Dynamic	397 MB	380 MB	424 MB	398 MB
PCIe Link Speed	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s

on your graphics card’s mining performance. NBMiner works with Ethereum mining, and it reports core statistics such as power, GPU core temperature, and memory temperature.

Now go look at your memory temperature (“MTmp” if you’re using NBMiner). There’s a good chance you’ll see that it’s in the 90°C or higher range if you have GDDR6X memory, which is the case for the RTX 3070 Ti and above. All four cards that we refurbished for this article were hitting 110°C before throttling GPU clocks to try to avoid overheating.

If your card hits 100°C or more, you have an

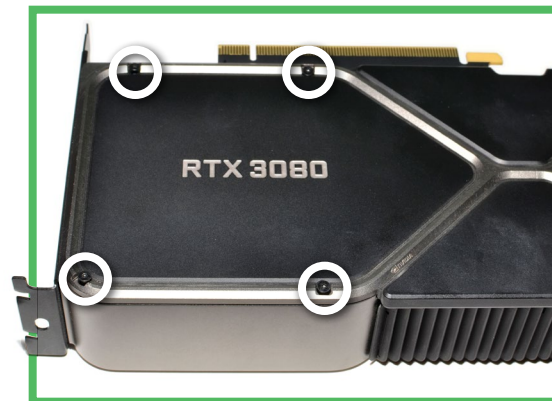
Running HWInfo64 lets you know how hot your GDDR6X memory is getting. It also reports memory temperatures on AMD’s RX 6000-series GPUs.

excellent candidate for thermal pad replacement—doubly so if your card hits 110°C or 112°C, which is the highest we’ve ever seen before severe throttling kicks in and the fans ramp up to 100 percent. There are a few high-end GPUs that come with better memory cooling and thermal pads, but even “good” cards rarely have pads that can match the performance of what we used (see “Choose a Good Thermal Pad”).

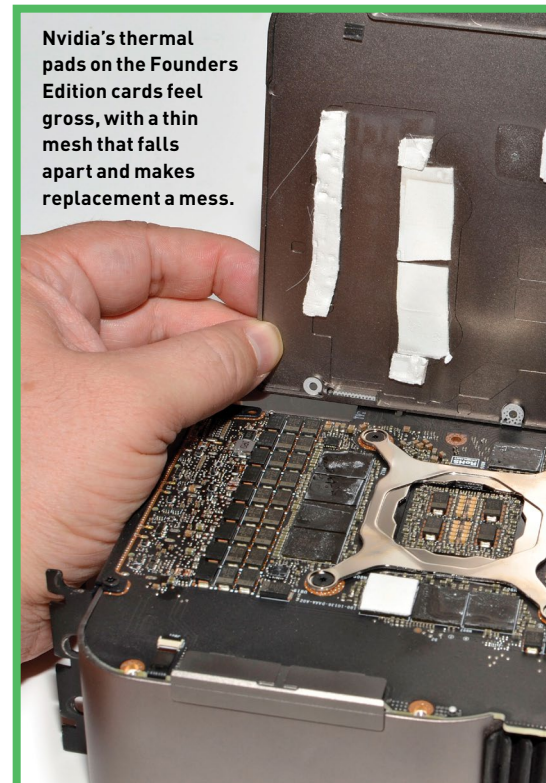
replacing screws. This is particularly important when you get to the bracket around the GPU core, which applies more force in order to ensure good contact between the chip surface and the heatsink plate. Again, keep track of where everything goes because you’ll eventually want to reverse the order and put everything back together. Once all the screws have been removed, along with any cables that might hold the PCB in

place, you should be able to pull the PCB away from the heatsink without too much difficulty. The thermal pads and thermal paste on the GPU are somewhat sticky, so the PCB won’t just pop right off, but if it feels like it’s stuck, double-check and ensure you didn’t miss a screw.

Most graphics cards only have memory chips on one side of the PCB, which definitely makes things easier. The RTX 3090 cards are the exception to this

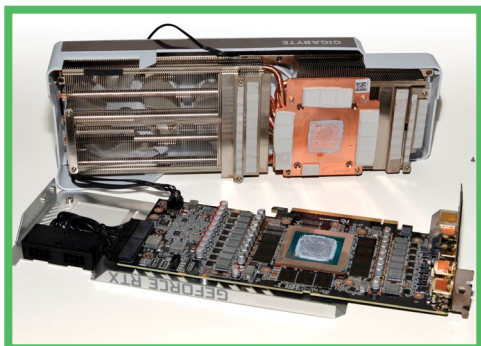


The magnetic covers hiding these Torx screws can be removed using a piece of tape.



Nvidia’s thermal pads on the Founders Edition cards feel gross, with a thin mesh that falls apart and makes replacement a mess.

because they have 24 1GB GDDR6X chips in “clamshell” mode, where each memory mounting location gets chips on both sides of the PCB and they share the 32-bit interface. The more recent RTX 3090 Ti switched to 2GB chips, which helps with cooling as well since the memory on the back of the PCB with RTX 3090 cards usually didn’t benefit from active cooling. If you’re servicing an RTX 3090, you should replace the thermal pads on both sides. That may require a bit more work, though with the 3080 and 3090 Founders Edition cards, getting to the main side and the GPU requires that you first expose the back of the PCB. Regardless, you need



If you've done everything properly, you should be able to pry apart the heatsink and cooling shroud from the PCB and backplate with minimal force.



twice as much thermal pad material for a 3090 compared to a 3080 Ti or 3080.

TAKE IT TO THE CLEANERS

Now comes the "fun" part, where you get to remove the old thermal pads, clean off any residue, then put new pads in place. As with so many other details, how difficult this is can vary wildly between GPU models. Nvidia's cards have thermal paste that feels, in our opinion, disgusting and tends to stick around more than we'd like. The Asus card's pads were more like clay, which wasn't much better as they tended to break apart. Gigabyte's pads were the easiest to remove, but their

BEFORE & AFTER

The only way to truly know how much new pads and cleaning help is to take measurements, before and after. We did extra testing with the Gigabyte RTX 3080 Vision, as it seemed to need the most help from the start, but we also did limited testing with the other GPUs. The results were quite impressive.

Even from the start, gaming performance wasn't a serious concern. The Gigabyte Vision seemed to be about as fast as other RTX 3080 cards, though we did notice that fan speeds and memory temperatures were higher than expected. We checked performance in four games, as well as with Ethereum mining, and recorded the results. Then we blasted out all the dust—there was a lot—and cleaned up the card before testing again. Cleaning the card only took about five minutes, but it also didn't seem to improve the situation much. Finally,

we checked performance after replacing the pads.

In terms of average frame rates, the biggest change was still within one percent of the original result. That might seem like this whole exercise was a waste of time and effort, but checking temperatures tells a different story. Blowing out the dust and doing a normal clean dropped the GPU core temperatures by about 3°C, and memory temperatures were 2°C lower. Fan speeds, on the other hand, dropped by around 400rpm, which is a bit more useful. The real story was with the thermal pad replacement.

While the performance didn't change and fan speeds remained about

Your newly cleaned and refurbished card probably doesn't look too different from the outside, but it's what's inside that counts.

the same as after cleaning, the memory temperatures dropped by 24°C in all four games. We went from an initial GDDR6X range of 100°C–106°C while gaming, to 96–106°C with the cleaned card, to just 74–80°C after replacing the thermal pads. With our worst-case Ethereum mining test, the card went from averaging 72MH/s with 110°C memory temperature in both the dirty and clean tests, to being able to reach 92MH/s with the memory at 92°C after thermal pad replacement.

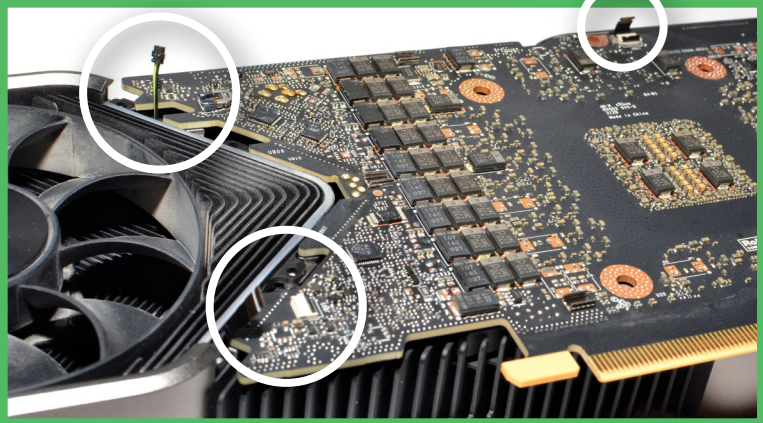
heat conductivity was the worst of all the cards. If you have a small plastic scraping tool of some form, it helps quite a bit with removing the thermal pads. You can just use your fingernails in a pinch, but that usually results in getting a bunch of gunk stuck under your nails. The thermal pads are usually about half an inch wide—the width of the GDDR6X chips—and you don't want to use anything too hard or sharp as you could damage something if you slip. Besides the cooling pads on the memory, most cards have pads on some of the VRMs. While VRMs do generate some heat, they normally don't get nearly as hot as GDDR6X, so you can leave those

pads in place if you like. That's what we did with the cards we refurbished. With pads removed, you can proceed with cleaning off the GPU, heatsink, memory, and other surfaces. You can use Q-tips and isopropyl alcohol, or wipe away any residue with a lint-free cloth. Take your time and be thorough, though a few stray bits likely won't matter. The original thermal pads and paste should be non-conductive, just like the replacement pads and paste, so it won't hurt if there's some excess.

MEASURE TWICE, CUT ONCE

The replacement thermal pads usually come in a single large sheet, and you





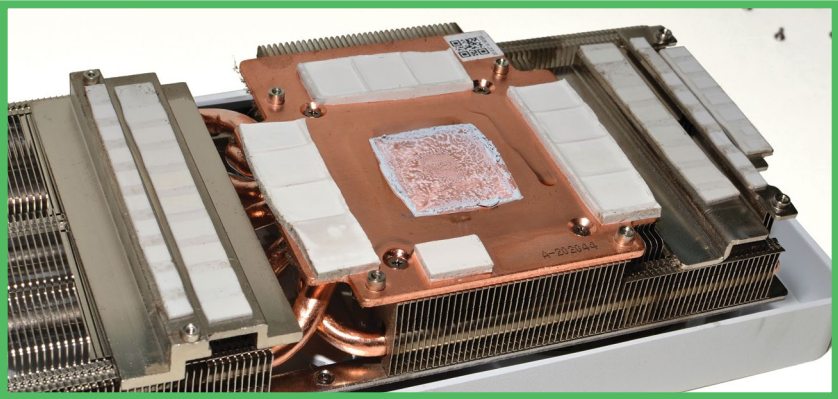
Check for any cables that might hold the PCB in place, such as the two small ribbon cables and the two-wire LED connector on this 3080 FE.



RTX 3080 cards only use ten of the potential 12 memory locations, but the two that are missing can vary depending on chip binning.

need to cut pieces to size to cover your memory—and VRMs, should you opt to do those as well. It's fine to be off a little, either slightly too large or too small, so you don't need to be exact. We just held the sheet up to the memory chips to get an approximate width, then used scissors to cut off pieces. Some people prefer to use a cutting board and a sharp blade, such as an X-Acto knife, but it shouldn't matter either way. The new thermal pads should have plastic on both sides, as they're slightly sticky otherwise. Make sure to remove both sides or you'll seriously hamper the ability to transfer heat.

You can put the pads straight on the memory, or you can add a small dab of thermal paste for good measure. We used thermal paste—Arctic MX-4—but it's not strictly necessary. There's a potential exception to this, however, if you use pads that might otherwise be too thin—for example, replacing 2mm pads with 1.5mm pads. In that case, the thermal paste can help make up the difference and ensure there's no air gap. Ideally, you'll only replace the pads once, but the



Gigabyte's thermal pads came off easily, but they definitely didn't do a good job of transferring heat, as shown by our 24–26°C temperature drop.

new pads may also deteriorate over time. If that happens and you need to refurbish the card again in another year or two, any extra thermal paste you apply might come back to haunt you. Or at least irritate you. With the new pads in place, the only thing left to do is reverse the whole process and put the card back together. This should go faster than the disassembly since you're

already familiar with the card's design and how everything fits together.

PROOF IS IN THE PADDING

With your freshly serviced card in hand, it's now time to check it out and see if all that work was helpful. Hopefully, everything went smoothly and your card boots right up without issue. If not, you

GIGABYTE GEFORCE RTX 3080 VISION OC RESULTS									
	ORIGINAL DIRTY STATE			AFTER CLEANING			AFTER REPADDING		
	Performance (fps)	Fan Speed (rpm)	VRAM Temp (°C)	Performance (fps)	Fan Speed (rpm)	VRAM Temp (°C)	Performance (fps)	Fan Speed (rpm)	VRAM Temp (°C)
Borderlands 3	105.5	2,739	106	106.2	2,011	104	107.4	2,094	80
Cyberpunk 2077	76.9	2,517	106	77.3	1,978	106	77.4	2,002	80
Forza Horizon 5	101	2,064	100	101	1,872	96	101	1,847	74
Metro Exodus Enhanced	83.1	2,145	104	83.2	2,086	102	83.3	2,091	78

A LOOK AHEAD TO NEXT-GENERATION GPUS



The cryptocurrency boom and bust cycle has happened before—first in the HD 5870 and HD 6970 era back in 2011, then with R9 290/290X in late 2013 and early 2014, and more recently in late 2017 and early 2018 with AMD's RX Vega and 500-series and Nvidia's GTX 10-series GPUs. This latest cryptocurrency bubble lasted longer than before, likely in large part thanks to the pandemic and the ensuing supply chain issues. While it's difficult to say exactly how this latest

cycle will impact graphics cards and the upcoming launches, it's likely to be significant.

All signs indicate that AMD and Nvidia are finally getting a sufficient supply of their current-generation GPUs to meet demand, and while graphics card makers and retail outlets have been slow to drop prices to "normal" levels, we're seeing more and more promotions that are clearly trying to sell as many cards as possible while prices are still high. Meanwhile, the Nvidia Ada and AMD

RDNA 3 architectures are supposed to arrive before the end of 2022. We're looking forward to some big improvements, hopefully at prices people can afford, and without the scalper shenanigans that plagued the RTX 30- and RX 6000-series cards.

One interesting tidbit is that the Ethereum network's hash rate increased from around 223TH/s in September 2020 to a high of 1,127TH/s in May 2022. That's a 5x increase in hash rate, but more importantly,

the extra 904MH/s would require nearly eight million RTX 3090 GPUs just to reach that figure. Most of the mining power obviously didn't come from RTX 3090 cards, which means there could be close to 20 million current and previous-generation GPUs mining Ethereum.

If the current trends hold and potential mining profits keep dropping, the future AMD and Nvidia architectures will face a lot of pressure from used cards being sold at lower

Future graphics cards could help to power the metaverse, but probably not for a few more generations of technology.

prices. That would be a nice change of pace and might serve to keep the hypothetical RTX 4080 and RX 7800 XT priced similarly to the outgoing RTX 3080 and RX 6800 XT, rather than seeing them jump to \$1,000 or more. Whatever the prices end up being, we can only hope availability will be better than we saw during 2020 and 2021.

WHAT ABOUT AMD CARDS?

We've focused on Nvidia's RTX 3090 and 3080 cards for our refurbishing treatment, but the same principles potentially apply to any other graphics card. AMD's RX 6000-series GPUs have been around for nearly two years as well, and they were also used for cryptocurrency mining. The difference comes down to temperatures and power requirements.

Even after tuning, an RTX 3090 might draw nearly 300W of power and the memory can run at anywhere from 90°C to 110°C, depending on the model and whether the thermal pads were replaced. The RTX 3080 cards by comparison use about 225W, but again with GDDR6X memory running at 90–110°C. For mining purposes, the fastest RX 6900 XT, RX 6800 XT, and RX 6800 all top out at around 175W of power use, and the memory usually sits at less than 90°C.

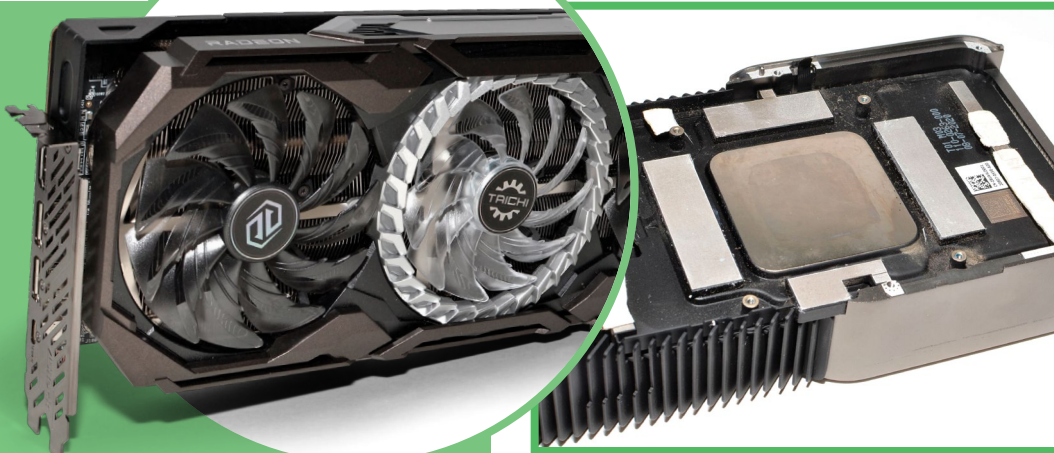
The net result is that the fans don't need to

work nearly as hard, which means far less wear and tear on the hardware in general. Dust build-up can still be a problem, and cards could still benefit from replacing the thermal pads and thermal paste. You might end up with memory temperatures of 60°C instead of 80°C while gaming, but that's unlikely to affect gaming performance in the slightest.

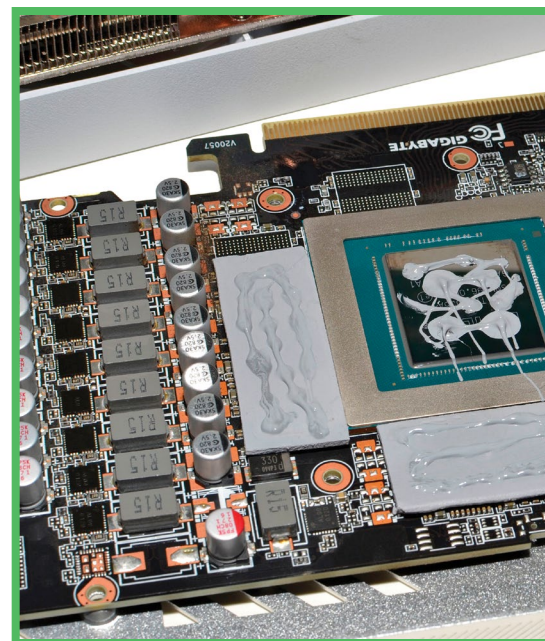
The same goes for previous-generation graphics cards, although because they're older, there's a good chance they will benefit from putting on new pads and paste. Both can deteriorate over time,

AMD cards such as this ASRock RX 6800 XT Taichi might also benefit from a thermal pad overhaul, but their GDDR6 memory doesn't tend to run nearly as hot as Nvidia's GDDR6X models.

and we've seen plenty of cards from the RX Vega and GTX 1080 era that clearly weren't performing as well as they did when they were brand new. Check the temperatures and clock speeds, and if you see a rapid drop in clocks over time with increasing temperatures, that's a good sign you should tear down the card and clean things up.



We've cleaned the old paste and pads off this RTX 3080 FE and it's ready for the good stuff.



may need to partially disassemble the card and check all the connections. In case this wasn't clear, though dismantling and servicing a graphics card isn't terribly difficult, there's certainly the potential to muck things up and kill your card. We didn't have any issues with our four test subjects, but we've taken graphics cards apart many times over the years.

You can see from our testing results on page 22, that even without cleaning, performance in games wasn't all that different, but we knew from the start that memory temperatures were the biggest issue with most of these cards. The Gigabyte RTX 3080 Vision had high memory temperatures and relatively high fan speeds in games, and with Ethereum mining as a stress test, it was a joke—it only managed 72MH/s, whereas

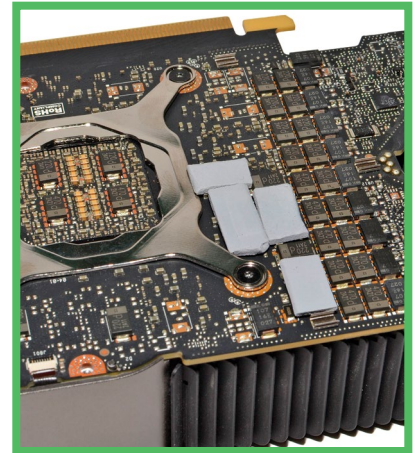
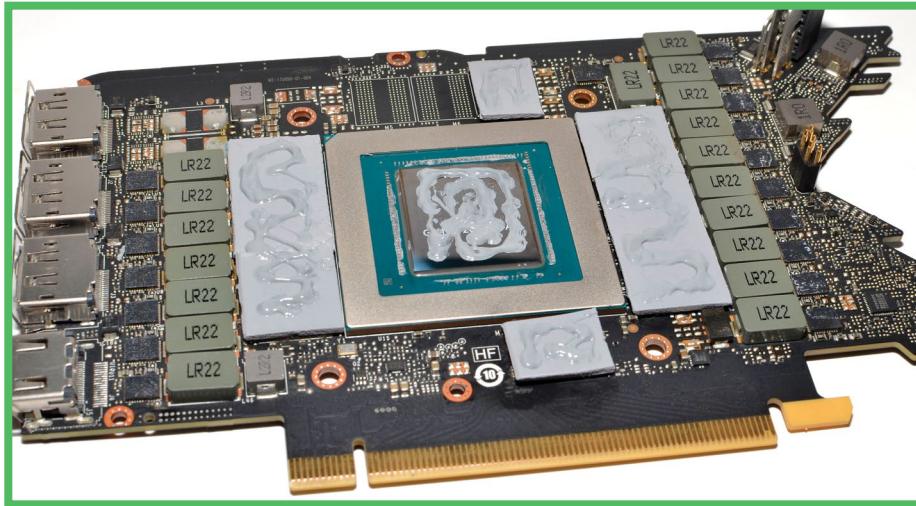
a good RTX 3080 could easily do 90MH/s or more. Replacing the thermal pads changed all that, and now it's one of the coolest-running 3080 cards we've seen.

The other three cards showed similar gains in memory temperatures. The RTX 3090 Founders Edition now sits at 90°C instead of 110°C with Ethereum mining, doing 114MH/s instead of 104MH/s. The Asus RTX 3090 showed the smallest gains, now hitting 100°C on the memory while mining at the same speed, but it takes much longer for the memory to hit that temperature. The RTX 3080 Founders Edition, meanwhile, can manage 95MH/s at 88°C on its memory, compared to 84MH/s and 110°C at the start.

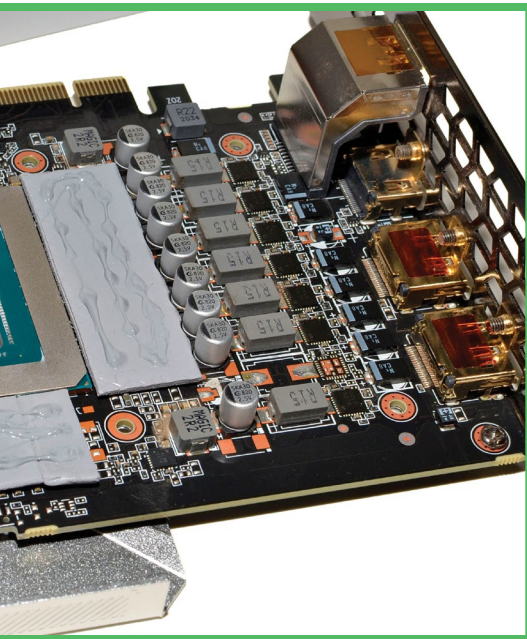
While all those results focus on Ethereum mining, that's only because it's the most demanding test scenario

we've found for graphics card memory temperatures. Games aren't nearly as strenuous, but most of the cards were getting close to 100°C before and now typically stay closer to 80°C.

Perhaps it doesn't matter too much, because Nvidia rates the GDDR6X for up to 110°C, and the memory can supposedly handle up to 120°C without failing—meaning Nvidia builds in a 10°C buffer and starts throttling heavily if your GPU ever reaches 110°C. Still, we've been using computers long enough to know that lower temperatures are preferable, especially when it comes to graphics card longevity. Even the oldest RTX 3080 cards are only just hitting the two-year mark, and we suspect most won't be running at all in another year or two if they're mining 24/7 at 110°C. That



If you have extra padding, the 'hot spot' sensor on Nvidia cards is offset slightly.



We put thermal paste on both sides of the new thermal pads to ensure better heat transfer, but it can make things messier if you ever disassemble the card again.



PICK A GOOD THERMAL PASTE

For cooling your GPU memory, thermal pads are the primary factor. However, you also need to clean off whatever thermal compound was used on the GPU core and reapply fresh thermal paste. As with thermal pads, there are plenty of options and factors to consider.

One of the best thermal pastes right now is ProLimaTech's PK-3 Nano Aluminum. With a thermal conductivity rating of 11.2W/mK, it might seem like it's not even as good as the thermal pads we selected. The difference is that thermal paste is more about filling in the tiny air gap between the

GPU chip surface and the heatsink, which will be much thinner than the 0.5–2.0mm gap between the memory chips and your cooler.

Why don't GPUs just have the cooler attach directly to the heatsink and use thermal paste? We've wondered the same thing, and it probably comes down to ease of application. Most GPUs are covered in far more thermal paste than necessary, and it's usually not premium quality stuff like the PK-3 Nano. In fact, it's more like clay in our experience, and we'd be curious to know the thermal conductivity rating of the stuff



You'll want a good thermal paste on your GPU. While it's not necessarily the best option, we had plenty of Arctic MX-4 on hand.

used by graphics card manufacturers.

Because thermal paste can easily get on other bits and pieces, it's important to use electrically non-conductive options. Liquid metal might improve cooling performance, but if a drop gets in the wrong spot, you can kiss your GPU goodbye.

doesn't mean we recommend mining at this point, nor do we recommend going out and buying a used card that's been mining 24/7 for the past 18 months. And to be clear, if you see a used RTX 3080 or RTX 3090 online, it's probably been mining for the past year or more. Still, if you can get a great deal and have a way to test the card beforehand, or get a refund if it has problems, we might soon see cards approach prices that are too tempting for some of us to resist.

The widespread availability of used previous-generation cards may also result in more competitive prices on the upcoming Nvidia Ada and AMD RDNA 3 graphics cards. That would be a nice change of pace after the past two years of massively overpriced and largely unavailable GPUs. ⚡

BUILD YOUR OWN NAS

Nick Peers extols the virtues of building your own network storage device

EVERYONE NEEDS a server—a centralized machine doing what it says on the tin, namely serving the various needs of your network. Whether you're a media lover (Plex), distrust online services (Nextcloud, self-hosted Bitwarden) or simply want a central shared folder with 24/7 access for everyone, a server has you covered.

The obvious thing to do is purchase a dedicated machine for the task—a NAS such as those offered by QNAP or Synology are effectively mini-PCs designed to meet all your needs. So why build your own? Aside from the fact it's what we do on *Maximum PC*, building your own server

allows you complete control over its spec. You're also free from manufacturer constraints: instead of a proprietary operating system with a finite shelf life, you get to work with a popular open-source OS that offers ten years' rolling support for each LTS version released. Your self-built server will outlast any proprietary NAS.

So join us as we reveal all you need to spec the perfect server. We'll run through putting it all together, plus get you set up, from installing Ubuntu Server and a web front end for headless access to tweaking the UEFI to eke even more power savings. Enough idle chat, let's get cracking...



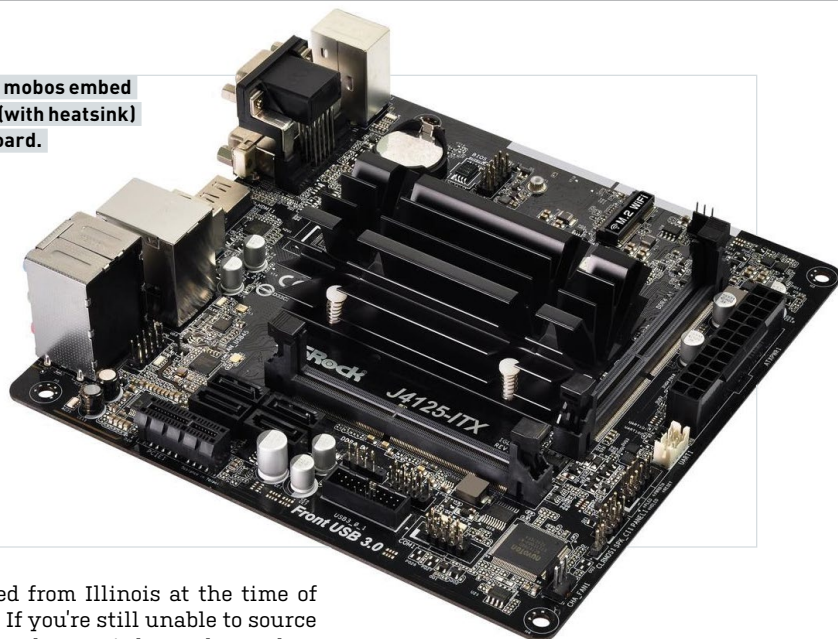
LET'S START by spec'ing out your NAS server. We're looking for a machine capable of running 24/7 without making too much impact on your energy bills. That means a suitably low-wattage system with the added benefit of being as quiet as possible. The solution can be found with Intel's Pentium and Celeron J-series processors, which you'll find in mid-range QNAP and Synology NASes as well as barebone mini NUC PCs.

You won't be compromising on performance—these are quad-core processors with support for hardware-accelerated UHD graphics, so are perfect for on-the-fly transcoding of Plex media streams, for example. Yet the chips—embedded directly into the motherboards—draw so little power (10W maximum) that they're cooled solely with a heatsink.

There's one fly in the ointment—such boards can be difficult to source. I got lucky back in late 2020 with my J5040-ITX board from ASRock, but these days you're more likely to land one of its slightly less-powerful siblings, the ASRock J5005-ITX or Celeron-based ASRock J4125-ITX. No matter, all three quad-core processors make for a superb base for your system, if you can find them.

You may have to look to import from elsewhere for a premium (try www.mini-itx.com, a UK-based company that ships to the US) or scour the likes of eBay for US-based sellers. We saw several J4125-ITX boards available from \$110, and one J5005-ITX being

J-series mobos embed the chip (with heatsink) on the board.



auctioned from Illinois at the time of writing. If you're still unable to source a board or the cost is beyond you, then check out the box for an alternative approach that pairs a barebones Intel NUC with a NAS-like enclosure. Not quite as elegant, maybe, but equally as effective.

FLESH OUT YOUR SPEC

If you're lucky enough to source one of these boards or something similar, then the next thing is to locate a suitable case to house them in. Our current recommendation is the JONSBO N1 Mini-ITX NAS Chassis (\$150, www.newegg.com/p/2AM-006A-00074).

The case comes with five 3.5-inch removable drive caddies connected to a server-grade SAS backplane, and there's also an internal 2.5-inch bay for a fast SSD boot drive.

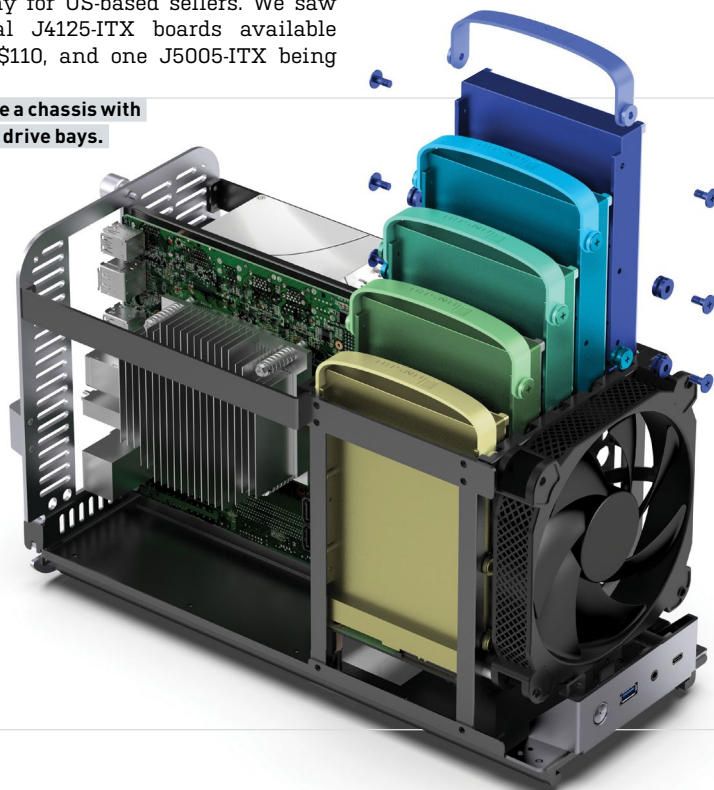
A front-mounted 14cm fan helps cool the drives, and there's space for one half-height PCIe expansion card. The chassis can be placed on its belly or stood upright—in the latter configuration, its footprint is 210mm x 170mm, with a height of 354mm.

You'll need to supply your own SFX form-factor PSU—raw power isn't important as five 3.5-inch drives and one 2.5-inch SSD drive draw less than 50 watts combined at full use (so significantly less in reality). If money is no object, the Seasonic FOCUS SGX-650 (\$149, <https://www.amazon.com/dp/B09NZG8GR8>) ticks all the boxes and comes with a decent ten-year warranty. Too expensive? Try the EVGA SuperNOVA 450 GM (\$85, <https://www.amazon.com/dp/B07JFLNG3B>). The 450-watt model will be more than ample for your needs, although the 650W model is currently just \$5 more.

You'll also need to invest in some SATA cables with right-angled connectors at one end to connect the SAS backplate to the mobo due to the lack of space between it and the case. Shop around for multi-pack deals—a three-pack 12-inch SATA cable connection costs around \$6 on Newegg (www.newegg.com/p/N82E16812119910), for example.

The last thing you need to fill out your core spec is RAM. ASRock's J-series boards officially support up

Choose a chassis with lots of drive bays.



to 8GB DDR4 SO-DIMM RAM, which is what Crucial's website will tell you when you search by model. Yet ASRock's own website tells a different story. Its Memory QVL pages (such as www.asrock.com/mb/Intel/J4125-ITX/index.asp#Memory) admit that its boards can support up to 32GB, installed as a pair of 16GB sticks.

A happy medium is 16GB, two Crucial 8GB DDR4-24000 SO-DIMMs cost \$64 in total (www.crucial.com/memory/ddr4/ct8g4sfs824a). These have happily powered my J5040-ITX for the last 18 months.

STORAGE

Now it's time to meet your server's storage needs. For this, we're going to recommend drives built specifically for the demands of a NAS system—in this case, Western Digital's Red series, although other manufacturers offer similar options too: Seagate's IronWolf or Toshiba's N300 series, for example. The beauty of our modular system is that you can start with just two drives (your boot drive and one storage drive) and then add additional drives as budget and needs allow, or you can temporarily reuse unused drives from other systems to build out the capacity, accepting they won't be optimized for NAS use.

Confusingly, there are three distinct types of WD Red to choose from: WD Red, WD Red Plus, and WD Red Pro. We recommend either WD Red or WD Red Plus. Both are designed for 24/7 use and use 'IntelliPower' to vary the speed to save energy, but the WD Red Plus is also optimized for RAID setups should you want to go down that route (see the box).

First, you need an SSD boot drive. The good news is that WD offers the

WD Red SA500 explicitly for NAS use: the entry-level 500GB model can be had for under \$70 from the usual retailers (see www.westerndigital.com/products/internal-drives/wd-red-sata-2-5-ssd for details). 1TB, 2TB, and 4TB models are also available, but overkill for most who will be content to store the bulk of their data on slower 3.5-inch drives.

When it comes to the larger capacity WD Red 3.5-inch drives, the good news is that there isn't a huge premium to pay over regular internal SATA drives. The 4TB model can be had for under \$70, while capacities up to 14TB (just \$210 from Western Digital at the time of writing) can also be had. That gives your NAS a theoretical maximum capacity of 74TB (including boot drive), although 20TB (5x 4TB) should be more than enough for most, including the most ardent media ripper.

OTHER CONSIDERATIONS

As things stand, we're assuming you'll connect your NAS to the network via Ethernet cable. This ensures it's able to copy data and stream media at maximum speed, and thanks to the headless nature of your NAS is a practical option if the router isn't conveniently placed on or near your desk. If not, then a USB Wi-Fi adapter is the cheapest and simplest way to turn your device into a wireless one.

An extra investment, particularly if you plan to use all six available drive ports in your case, is to add another SATA controller to your mobo. All three ASRock boards offer a maximum of four SATA ports but come with a single PCI-E 2.0 x1 port that can accommodate a PCI-E SATA controller card.

You'll find plenty of options on sites such as newegg.com or eBay for around \$15-20 for two-port models (taking your total number of SATA ports to six), but make sure it has a low-profile bracket to fit your case.

Finally, you'll want to protect your 24/7 server (or however many hours each day you have it running) from power outages. The obvious fix here is to invest in a UPS to avoid potential data loss while you either fix the outage (say by flicking the trip switch) or perform a graceful shutdown of the NAS itself. If this is all you need, then a model like APC's Back-UPS 450VA (\$45, www.bestbuy.com/site/6471519.p) will suffice, and you can use it to keep your router running too.

EVGA's SuperNOVA 450
GM is a good choice
for PSU.



TAKE THE MINI-NUC ROUTE

If you're struggling to source a suitable mini-ITX board to base your NAS around or looking for a simpler, cheaper option then consider pairing a mini-NUC PC with a dedicated NAS-style enclosure connected to the NUC via USB. The advantage of this approach is that Pentium Silver-based NUCs are widely available, such as Intel's Pentium Silver J5005 barebone NUC (\$220, www.newegg.com/p/N82E16856102319).

Just add RAM (up to 8GB) and an SSD boot drive and you're good to go—it even has Wi-Fi onboard alongside four USB ports, two HDMI ports, and an Ethernet port. Equipping this with 8GB RAM from Crucial and a WD Red SA500 500GB SSD drive would set you back around \$100 in total, bringing the total cost to around \$325 for your main server.

You're then left with sourcing a suitable NAS-style enclosure, such as TerraMaster's D5-300C (\$176, www.amazon.com/dp/B06ZY6DK8N), a five-bay enclosure with RAID 0, 1, and 5 support on the first two drives if needed. Its power consumption equates to what you'd expect from five drives—just under 50 watts under a full load.

Fit two 4TB WD Red Plus drives to get started for a combined \$140 and you're looking at a total outlay of around \$650 for your NAS setup with 8TB storage, with room for additional storage as and when you need it.



Pair this with an Intel NUC for an alternative NAS.

RAID OR NOT

Whether you go down the self-build or mini-NUC route, you'll be left with a NAS that supports RAID to varying degrees. A quick reminder: RAID (redundant array of inexpensive disks) combines two or more physical disks into one or more logical units known as a RAID array.

There are different types ('levels') of RAID array, each of which does different things for different reasons. For starters, RAID 0 takes multiple drives and converts them into a single drive, splitting files across all drives in a process called 'striping'. This improves drive performance as data can be read from and written to all drives simultaneously, however, it offers no protection—if one drive fails, then data is lost across all the drives in that array.

RAID 1 does the opposite: it takes two or more drives of equal capacity and 'mirrors' the content of each drive. So, if you have three 4TB drives in a RAID 1 array, your drive capacity remains at 4TB, but if one of the drives physically dies, no data is lost because it has been mirrored on the other drives.

There are six basic RAID levels in general, but RAID 0 and RAID 1 are the most common. It's possible to combine RAID levels, for example, RAID 1+0 (also known as RAID 10) creates a striped array from a series of mirrored drives to provide both performance and redundancy.

Do you need RAID? It can be fiddly to set up, and while RAID 1 offers protection against physical drive failure, it doesn't protect against other forms of data loss—accidentally deleted files, scrambled files from ransomware, and so on. In other words, even with a RAID array in place, you'll still need a strong backup regimen.

If you want to instruct your NAS to shut down automatically once the battery drops beyond a certain level for an additional layer of protection (in case you're not at home when the outage occurs), you'll need to spend more on a Smart UPS, one which can be hooked up to your network or NAS to allow it to control the NAS remotely.

The best deal we could find is the Tripp-Lite 1000 VA Smart UPS Back Up (\$190, <https://www.newegg.com/p/N82E16842111555>). The upside of investing in this model is that it has enough power to protect a range of devices, not just your NAS. Once you've connected the UPS to your NAS using the supplied USB cable, you'll need to configure Ubuntu's nut (Network Up Tools, <https://networkupstools.org/>) tool. See <https://zackreed.me/installing-nut-on-ubuntu/> for one of many guides to using nut with the usbid-ups driver that supports the Tripp-Lite 1000 VA.

BUILD YOUR NAS

There are no specialist skills required to put your NAS together. The same techniques you've used with previous *Maximum PC* builds will also apply here. But there are a few tips to help make the build go smoothly, along with some specific advice when it comes to configuring your SATA connections.

First, you're dealing with a snug chassis, so the order in which you install things is critical. Start by attaching the four legs to the back panel, even if you don't intend to stand the case vertically permanently. Doing this for the build process helps, not least when sliding the outer case back over the main shell.



A Smart UPS will shut down your server gracefully.

Some users have also complained about the drives getting 'toasty' due to the lack of airspace between the front-mounted fan and the drives themselves. Removing the decorative plate mounted on the front (it's attached to the inside of the shell using four screws) reveals a mesh front panel that improves airflow and greatly reduces drive temperatures to help extend their life.

You can download a user manual for the N1 case direct from Jonsbo (www.jonsbo.com/en/products/N1.html) if it's not supplied. This reveals the recommended order of installation: first, the mobo, then the RAM and PCI-E SATA card. Next, connect the SATA cables, which requires some thought.

First, identify which two of the J-series mobo's SATA ports use the Intel chipset—these will be marked SATA3_1 and SATA3_2 respectively. These are the fastest ports on the board, so make sure your boot drive is connected to SATA3_1. The other two SATA ports, SATA3_A1 and SATA3_A2, use the ASMedia ASM1061 chipset, which shares bandwidth with the PCI-E port (and therefore any additional SATA ports you add). Don't worry, there's plenty of bandwidth to ensure the slower 3.5-inch drives run at their best speeds.



Experiment with fan speed settings if it's too loud.

Once you've hooked up the SATA cables—a maximum of five running from the SAS backplate to the mobo, while the cable plugged into port SATA3_1 is left loose—fit the PSU as directed to the case before plugging in those PSU modular connector cables you'll need: MB to the motherboard, PERIF for the SATA backplate, and SATA for the 2.5-inch drive.

Next, each 3.5-inch drive needs to be fitted to their respective rubber cases and then slid into the case until each connects snugly with the backplate below. Last, but not least, mount the boot drive just above the PSU using the two screws provided to secure it in place. Finally, finish connecting all missing cables, SATA and power, to your 2.5-inch drive, plus the case's front-mounted fan and front plugs (USB 3.0, power button, HD Audio, and power LED) to the relevant connectors on the mobo. These can be found conveniently clustered close to the SATA ports and PCI-E slot.

TEST YOUR BUILD

Perform some final checks making sure everything is connected securely. Now connect the NAS to your monitor and plug in a keyboard (no mouse required) and the network cable or Wi-Fi USB adapter. The moment of truth: press the power button and hopefully your new machine will power on and perform its first successful POST operation.

If it fails to boot, the usual troubleshooting steps apply: start by unplugging all the SATA drives and trying again, then remove the PCI-E card, if necessary, and try again. Once you've successfully got to the POST, you should then be able to start adding elements back one at a time.

After a successful POST, you should next enter the UEFI setup utility to check everything's been detected and configure your new build for life as a 24/7 machine. Use the Main menu to verify your RAM has been detected, and Advanced > Storage Configuration to both verify and identify which drives are attached to the four SATA ports on your mobo. Any drives connected via a PCI-E SATA port won't show up here, which is normal. If you can't identify a drive by its model number, click on it for more information, including serial number and capacity.

You might want to consider checking for any UEFI updates at this point. Navigate to Tool > Network Configuration to verify your NAS

can access the internet, plus select a download server. Choose the Internet Flash option, if an update is found, but the tool claims there's no connection, return to Network Configuration and choose a different server.

If your chassis fan is too loud, switch to the H/W Monitor setting and experiment with setting the 'Chassis Fan 1 Setting' to Automatic to configure it. Hopefully, the physical modification you made to the front of the case during the build process should render this unnecessary, but if not, you can configure a target temperature (50° is the default), source (CPU or mobo), and fan speed (set in levels from 1-9).

While you're in the UEFI, now is a good time to ensure all energy-saving tweaks have been applied (see box for details). Then it's a case of heading to the Security tab, where you can enable Secure Boot for additional security, and to the Boot menu to select your SSD drive (SATA3_1 if you followed our advice) as the first boot device.

Finally, save changes and exit. Your PC will reboot, but of course, you still won't boot anything because you've yet to install your OS. Let's rectify that.

INSTALL UBUNTU SERVER

Of course, you're free to install whatever OS you like, but we've chosen Ubuntu Server 22.04 LTS. There's no desktop environment to minimize resource usage—a desktop isn't necessary as we'll be adding tools to give us remote access via a web browser. Ubuntu is also one of the most popular distros, so well-supported, and will run on your server hardware for years, if not decades, to come.

TWEAK YOUR BIOS

To eke additional energy savings from your NAS, you'll need to comb through your UEFI settings. ASRock's J-series boards are relatively straightforward to navigate and most of the settings you need are found on the Advanced menu.

Start with CPU Configuration: leave Intel SpeedStep Technology and Turbo Mode enabled, and make sure Enhanced Halt State (C1E) is enabled too. Also, verify CPU C States Support is set to the highest available state—C6 on my J5040-ITX. Next, look under Chipset Configuration and experiment with the ASPM setting (it's Auto by default, but you might want to try L0sL1 to enable power saving on the hard drives connected through your PCI-E SATA card). Deep S5 will be set to Auto, but changes to Disabled if you decide to run your server on a schedule to save power when it's not being used (see 'Schedule your server' box).

If you find your NAS doesn't reboot or restore itself properly after power loss, set Restore on AC/Power Loss to 'Power Off' to force you to switch on manually, enter the UEFI, then save and exit to restore boot functionality.

There's one power-saving setting under Storage Configuration—SATA Aggressive Link Power Management, which should be set to Enabled. Note, only those drives directly attached to the SATA ports on your motherboard will show up here, so don't panic if all six aren't visible. Also, make sure 'Suspend to RAM' is set to Auto under ACPI Configuration.



Many energy-saving settings are found under CPU Configuration.

We've chosen the LTS build because major releases come once every two years instead of six months, and there's no pressure to update because each LTS release is supported for up to ten years (five years of full support, five years of extended security support), meaning you could technically run Ubuntu 22.04 until 2032.

Let's crack on. From your main PC, head to www.ubuntu.com/server and click 'Download Ubuntu Server' followed by 'Option 2: Manual server installation'. Finally, click the download link to save `ubuntu-22.04-live-server-amd64.iso` (1.47GB) to your PC, then use a tool such as Rufus (follow the guide at <https://ubuntu.com/tutorials/create-a-usb-stick-on-windows#1-overview>) to copy it to an unused USB flash drive (2GB or larger).

Plug the USB drive into your server and reboot your PC. Try tapping F11 on startup to bring up the boot menu; if this doesn't work, enter the UEFI setup utility, navigate to the Exit tab, and select the USB flash drive from the Boot Override menu to boot from it.

You should see a boot menu (GRUB for those in the know) appear. Leave 'Try or Install Ubuntu Server' selected, and press Enter. The install process is a text-based affair, so wait while a series of messages scroll past on-screen as

Ubuntu initializes. Eventually, you'll find yourself on the first page of the install process—use the up and down arrow keys to move between options, plus Enter to select or deselect them.

First, select your language, then select 'Update to the new installer' for the latest version. After identifying or selecting your keyboard, you'll be prompted to select the 'base' for your installation. Leave the default install selected and press Enter again.

CONFIGURE NETWORKING

You'll now be prompted to set up your network connection. By default, DHCP will be selected, but servers should be given their own static IP address so they're always accessible from the same location. To do this, press the up arrow key twice to select your chosen interface (eth or wlan) and hit Enter to bring up a sub-menu. Select 'Edit IPv4', then hit Enter to highlight 'Automatic (DHCP)' and change it to Manual.

Now populate the required fields using the down arrow to move between them: enter `192.168.x.0/24` into the Subnet field, substituting x with the figure shown under DHCPv4. Now type your desired IP address into the Address field, making sure it

doesn't clash with any other network devices, and your router's IP address into the Gateway field.

'Name servers' is where you enter your chosen DNS servers—typically `8.8.8.8, 8.8.4.4` for Google, or `1.1.1.1, 1.0.0.1` for Cloudflare. The 'Search domains' field is only required if you want to append a local domain to hostnames across your network, for example, 'my.pc.mydomain.com'. If in doubt, simply leave it blank. Once done, select Save and hit Enter. You should see your new address listed next to 'static', so select Done and press Enter three times, skipping the proxy and Ubuntu archive mirror selection pages.

SET UP PARTITIONS

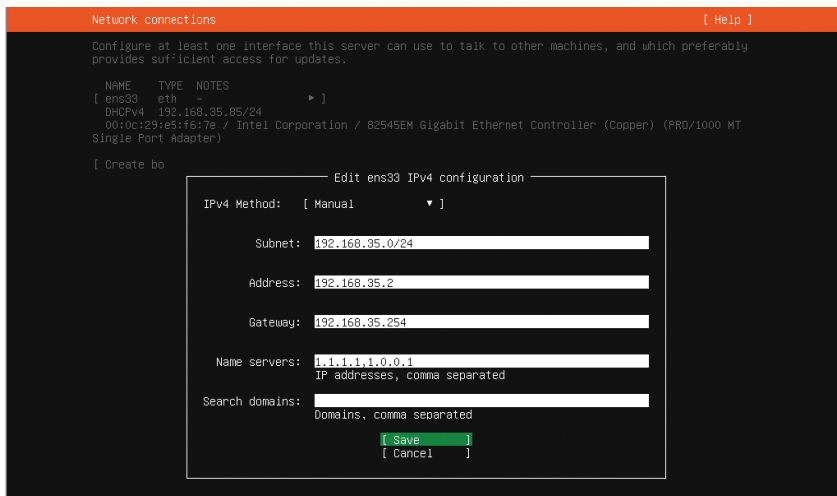
The 'Guided storage configuration' screen gives you the chance to partition your boot SSD disk as you see fit. The key is to verify `/dev/sda` is pointing to your SSD drive (identifiable by its size); otherwise leave 'Use an entire disk' selected along with 'Set up this disk as an LVM group' and select Done. Click Done again to accept the summary presented, and select Continue under 'Confirm destructive action'.

Next, set up your user account – enter your name, then name your server as you'd like it to appear on



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Give your server a static IP address for easy network access.

your network, whether generic ('file server') or specific ('js005-itx'). Provide a username and a strong, memorable password—you'll need this to log on to the server plus perform admin actions via the 'sudo' command. Select Done and hit Enter. You'll now be given the option of installing OpenSSH for secure remote access to your server via a command-line tool like putty—it's not strictly necessary given we'll give you access via your browser, so skip this for security reasons.

INSTALL EXTRA PACKAGES

You'll now be provided with a small list of additional server tools you can install via 'snap'. Select one and hit Enter to read more about it, plus choose which build (typically 'release' or 'stable') to install. Press Space to mark an item for installation (an asterisk will appear next to it). The two packages we strongly recommend you select here are docker and canonical-livepatch.

Select Done and hit Enter to finish setting up Ubuntu. A log screen will appear to reveal that the installer has been working behind the scenes and may now be all but finished. Wait for any security patches to be applied at which point 'Reboot now' will appear as an option. Select it, hit Enter, and wait for it to shut down and prompt you to 'remove the installation medium' at which point unplug your flash drive and hit Enter to reboot.

After a short pause, you should see your PC reboot, then Ubuntu Server load, displaying a string of status messages as it does so. Eventually, the screen will blank and you'll be

prompted to log in using the username and password you created earlier. If you opted to install docker and/or canonical-livepatch, then after a short pause, regardless of whether you've logged in or not, you'll see additional messages appear. When complete, hit Enter to resume logging in or to restore the command line.

INSTALL WEB UI

It's time to convert your server into a truly headless beast, liberating it from your display and keyboard (although you may need to occasionally plug these back in when troubleshooting boot problems in the future). To do this, we'll install a package called 'cockpit' (<https://cockpit-project.org/>). Start with the following command:

```
$ sudo apt update && sudo apt upgrade
```

This updates all outdated packages (yes, even after installation some

packages will need updating separately). If you see a dialog talking about daemons using updated libraries, select them all (press Space next to any not marked with an asterisk) and then press Enter. Next, time to install cockpit:

```
$ sudo apt install -t jammy-backports cockpit
```

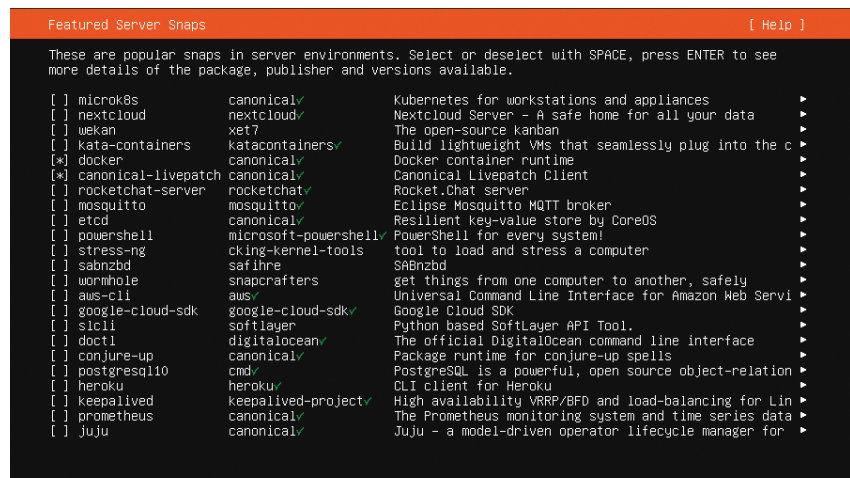
We've used the backports repository to ensure that cockpit not only installs the latest version but also remains updated going forward (around two new versions are released every month—see <https://cockpit-project.org/blog/> for details). Once installed, reboot your server:

```
$ sudo reboot
```

After rebooting, you should see a new message at the login screen revealing the 'web console' address (<https://192.168.x.y:9090>) is now available. Switch to your main PC and type this address into your browser. You should see a warning about a potential security risk, so click Advanced and select the option to continue.

You will be prompted to log into the cockpit web interface—simply enter your Ubuntu Server login details and click Log In to do so. You'll immediately see a prompt telling you have limited access: click 'Turn on administrative access' and re-enter your account password to switch to full access.

Here, you will see that cockpit provides a two-pane window, with a series of options on the left under System and Tools menus. Overview provides a handy summary of your server's status as well as options for shutting down and rebooting your system. Click 'View metrics and history' for a more detailed overview.



We recommend installing docker and live-patch alongside Ubuntu network access.

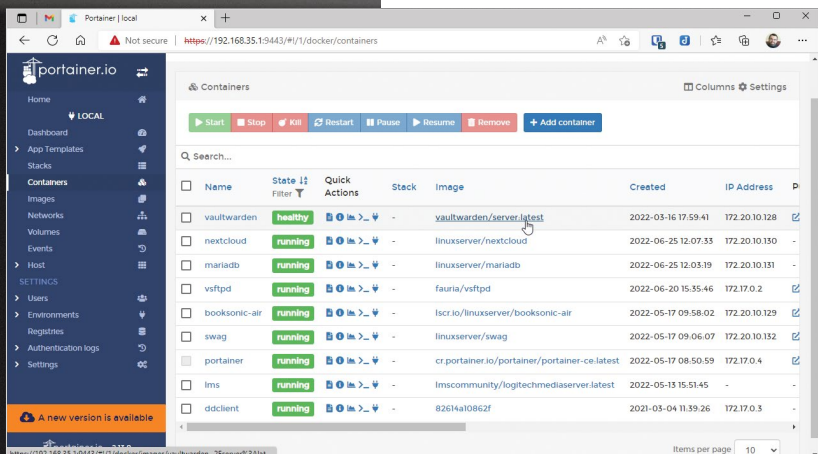
MAKE USE OF DOCKER

Sometimes it's best to run certain services in their own isolated environments. Not simply for security reasons, but to prevent bugs or crashes from bringing down your entire system. The simplest way to do this is with docker (www.docker.com), which creates virtualized environments inside which your chosen services run.

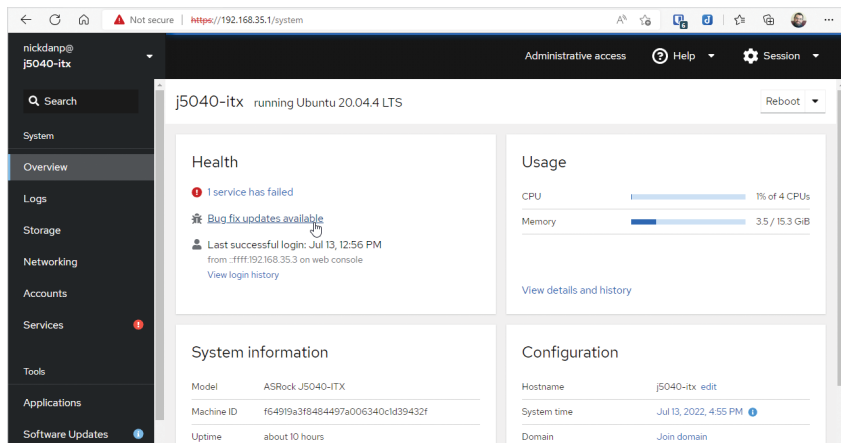
They can be linked to your network and folders stored on your hard drives, but the code inside is contained. If you run into problems, you can simply 'destroy' the container and start over, with your painstakingly configured preferences and data files left intact.

There are docker containers for almost every service imaginable, from FTP server (vsftpd) and password manager (Vaultwarden) to fully blown cloud backup (Nextcloud). Browse the extensive Docker Hub (<https://hub.docker.com/search>) for inspiration.

Containers can be created and run from the command line using a combination of environmental variables and both volume and port mapping. That's easy enough, but managing existing containers is fiddly in the Terminal. A better option is to use a third-party web GUI called Portainer. Guess what? It's distributed as a docker image, giving us an opportunity to showcase how it works. Head over to <https://docs.portainer.io/start/install/server/docker/linux> and follow the instructions to set it up.



Your server can handle multiple docker containers easily.



Manage your server remotely using cockpit network access.

You'll see a prompt to install cockpit-pcp, an add-on providing you access to metrics history going forward.

FIX COCKPIT NETWORKING ISSUES

If you try to install cockpit-pcp at this point, you will discover a problem: cockpit can't go online using Ubuntu Server's default network configuration daemon (networkd). Thankfully, the fix, which involves switching to NetworkManager, is relatively simple and affords us an early opportunity to explore cockpit's brilliant Terminal tool.

Select this under Tools and you'll see it's a superior version of the command line found in Ubuntu Server itself: easier to read (and customizable to boot), plus it supports tab autocomplete as well as copy and paste from other applications or web pages. Start with the following command:

```
$ sudo nano /etc/netplan/00-installer-config.yaml
```

This will open a configuration file. Add the following line beneath 'version: 2':

```
renderer: NetworkManager
```

Press Ctrl + X followed by Y and Enter to save your changes. Now reboot your server. Once you've logged back into cockpit, you should be able to install cockpit-pcp, plus keep your Ubuntu Server installation up to date via the Software Updates tool.

SET UP ADDITIONAL DRIVES

Take the time to explore other parts of cockpit, it's all largely self-explanatory, and as you can see, provides you with a powerful user interface for administering Ubuntu remotely. All that's left to do is set up your additional drives.

It's a relatively straightforward process but does assume a working knowledge of how Linux views drives and partitions—namely, they're mounted as folders known as 'mount points' within your filesystem. To keep access simple, we'll place these inside a 'media' folder that resides in your user's home folder.

To partition, format, and mount your new drives, navigate to the Storage section. On the right under Drives, you'll see all your physical drives, including those connected via the PCI-E card. One, /dev/sda, should already be configured as your boot drive, so click the next one in the list (/dev/sdb) to open its properties screen.

From here, click 'Create partition table' to initialize it (choose GPT over MBR) followed by 'Create partition'. Give it a recognizable name (say bay1) and set its filetype to EXT4. Leave the slider set to its maximum size and type /home/username/media/bay1 into

the Mount point box (substituting username with your actual Ubuntu username). Leave 'Mount now' ticked and click 'Create Partition'.

Once the partition has been created, repeat for any other drives (using bay2, bay3, and so on), then switch back to Terminal, type 'ls -l', and hit Enter. You should see a media folder has been created. The only problem? It's currently owned by 'root', which requires you to use 'sudo' to access it and your newly formatted drives. The solution is to change ownership of both media and its subfolders to your username. That's done with the following command (substitute both instances of 'username' with your own username):

```
$ sudo chown -R username:username media
```

Once done, you should navigate to the bay1 folder (cd media/bay1) and view its contents (ls -l) to verify the existence of a lost+found folder.

SHARE FOLDERS

Your drives are set up, configured, and accessible through cockpit, so the next logical step is to set up some shared folders for access across your network. You can share entire drives (bay1, bay2, and so on), but a better bet is to create individual shared folders so sensitive files remain off limits.

First, you need to install samba to support universal file sharing across any OS:

```
$ sudo apt install samba
```

Next, create your shared folder using the 'mkdir' command – for example:

```
$ mkdir ~/media/bay1/shared
```

Now it's time to tell samba the folder is shared:

```
$ sudo nano /etc/samba/smb.conf
```

Add the following code block to the bottom of the file (but substitute username with your username):

```
[shared]
comment = Ubuntu Shared
path = /home/username/media/bay1/shared
read only = no
browsable = yes
```

Add additional blocks for any other shared folders you wish to create, then save the file, exit samba and issue the following two commands:

```
$ sudo service smbd restart && sudo ufw allow samba
```

Finally, you need to assign a special samba password to your user account to gain access to the shared folder from other computers (make sure it's

different from your system password for obvious reasons):

```
$ sudo smbpasswd -a username
```

You should now be able to access the shared folders from other devices on your network using the username and password you just configured. If they don't show up automatically, type `\\192.168.x.y` (obviously substituting 192.168.x.y with your server's IP address) into a Folder Explorer window to manually access the shares.

FINAL THOUGHTS

And there you have it. You've specced and built your own low-power NAS-style server, installed a robust OS with long-term support, added the ability to configure it remotely, and set up your drives along with folder sharing. The world is now literally your oyster, but what's next?

First, we recommend taking a full system backup – our recommended CLI tool is timeshift:

```
$ sudo apt update && sudo apt install timeshift
```

```
$ sudo timeshift --create --comments "new backup" --tags W --snapshot-device /dev/sdb1
```

This will create a new backup on the drive designated as 'bay1' and update it weekly (-tags W). Should you need to restore it:

```
$ sudo timeshift --restore
```

You'll be stepped through the restore process, including choosing which snapshot to restore.

Now you're free to install services (such as Plex or Jellyfin) direct to your server or through docker (see the box opposite). Here's to your new NAS server providing you with many years of reliable service! ☺

SCHEDULE YOUR SERVER

Not everyone needs their server to be running 24/7, so if you're looking to maximize energy savings further, you'll be wanting to switch it off at night and then restart it the following morning. But why give yourself the hassle of remembering to do this when you can schedule it automatically?

This is a two-step process: first, instruct Ubuntu to shut down your server at a set time each day, then configure your UEFI to power on the server later. Let's start by configuring shutdown—switch to the Terminal in cockpit and issue the following command:

```
$ crontab -e
```

You'll be prompted to create a new crontab file – press 1 to use nano. The following line will shut down your PC every weekday at 02:00:

```
00 2 * * 1-5 root shutdown -h now
```

Press Ctrl + X followed by Y to save the file. You should see 'crontab: installing new crontab' indicating the file has been successfully processed. The line should be self-explanatory, but the crontab file comes with instructions for modifying this line if you need extra help.

That's half the job done, now reboot your server and enter the UEFI setup utility. Navigate to Advanced → ACPI Configuration and select RTC Alarm Power On. Select Every day then manually set the clock before hitting OK, saving your changes, and exiting.



Set your PC to power on automatically through the UEFI.

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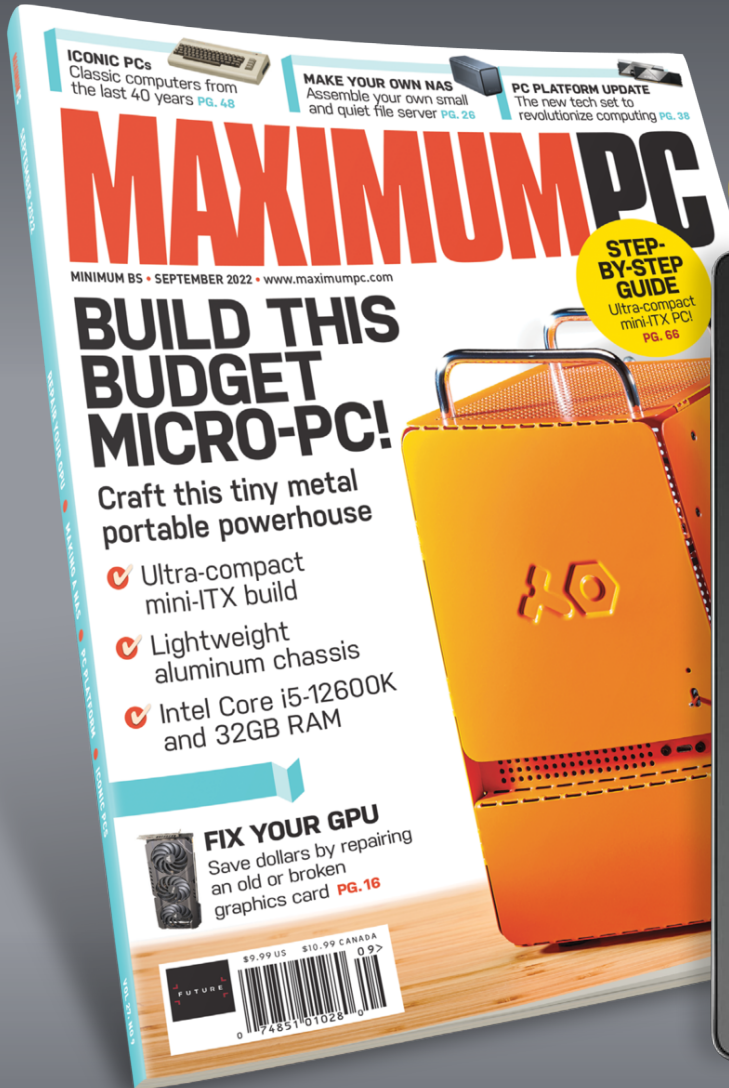
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GOING BIG ON BANDWIDTH THE FUTURE OF THE PC PLATFORM

Forget CPUs and GPUs. As Jeremy Laird explains, the PC's future is all about more bandwidth, for everything from storage to memory and even display interfaces

IF THE RUMORS and roadmaps are to be believed, the PC is about to enter a new golden age of innovation. Intel and AMD are prepping epic new processors, while Nvidia and AMD are tooling up to recalibrate expectations when it comes to generational performance increases with their next graphics cards. It's going to be explosive.

Yet there's so much more to the PC than just CPUs and GPUs. The PC platform itself and the peripheral technologies around it are just as important. Imagine storage tech hadn't advanced in the last

20 years. Or memory speeds. Or platform interlinks. Good luck gaming at 4K and 144Hz with that fancy GPU running over an AGP interface, your DDR memory chugging along at 100MHz, an 80GB magnetic HDD that cranks out less than 1MB/s of random access performance, and a video connector that tops out at 1080p and 60Hz.

You get the idea. The next few years are undeniably going to be exciting when it comes to those two headline-grabbing components, the CPU and the GPU, but there's plenty more going on with the PC....

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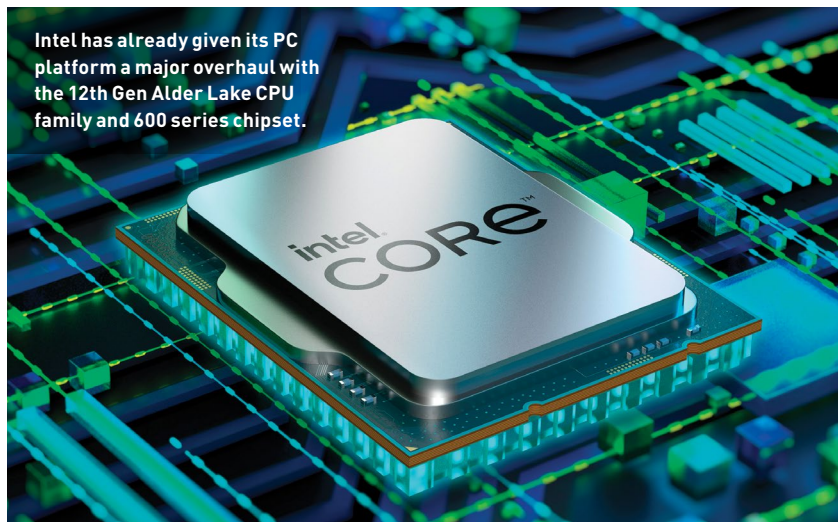


IF THE PC is ultimately a platform, let's start with the foundation to it all, the motherboard and motherboard chipsets. On the AMD side of the equation, we now have a pretty clear idea of what's coming next. CPU-wise, that's the Zen 4 architecture as found in the new Ryzen 7000 CPUs. Those new CPUs will slot into a new AM5 socket, which should be available to buy by the end of this year. Yup, the AM4 socket introduced six years ago is finally being replaced.

The good news is that not only does AM5 bring a new tranche of features and capabilities but, going on past AMD form, it should stick around for some time. Inevitably, there will be a cost penalty of being an early adopter of AM5 tech, but the expected longevity of the socket should allow for tasty upgrade opportunities down the road. And when we say upgrade opportunities, we're not just talking about the CPU. AM5 and the new chipset that comes with it lay the foundations for numerous platform upgrades.

Starting with the socket itself, AMD is finally making the move from the AM4 PGA or pin-grid array to LGA land-grid array. In simple terms, the pins move from the CPU to the socket, while the CPU itself is then fitted out with an array of contact pads. There are pros and cons to both systems. Arguably, the pins on a PGA CPU are easier to straighten than damaged pins in an LGA socket. On the other hand, a bust motherboard is likely cheaper to replace than a bent high-end CPU.

Whatever, AMD's new AM5 socket, also known as LGA1718 for the number of pins found within, certainly breaks backward compatibility with all previous AMD



Intel has already given its PC platform a major overhaul with the 12th Gen Alder Lake CPU family and 600 series chipset.

CPUs. But that is the price of progress and AM5 delivers plenty of that. First up, AM5 and Ryzen 7000 bring support for the latest Gen 5 version of PCI Express. The socket itself has 16 PCIe 5 lanes for the graphics card and getting on for 64GB/s of bandwidth to the CPU just for graphics. There are also two dedicated four-lane PCIe 5 direct-to-CPU interfaces for connecting storage, providing up to 16GB/s of theoretical SSD bandwidth.

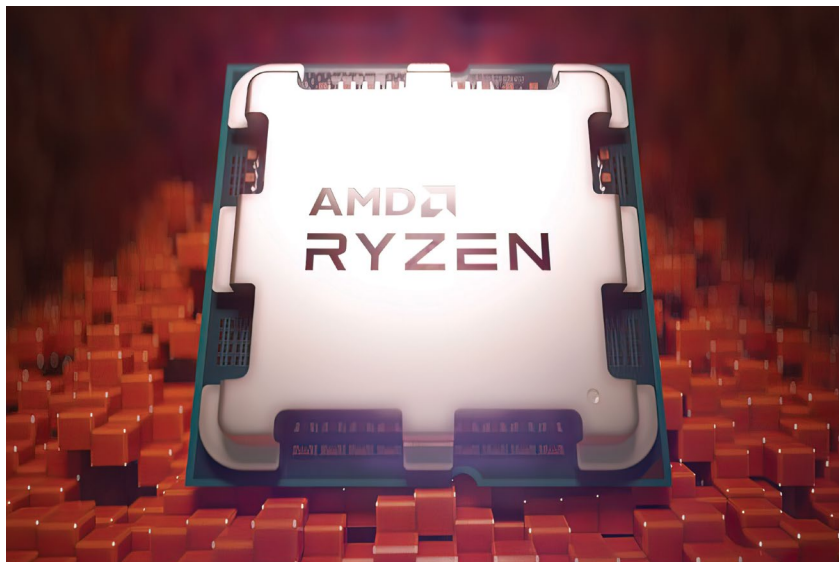
By way of comparison, the AM4 platform provided 24 lanes of PCIe Gen 4 direct to the CPU, including the chipset downlink, so AM5 has double the bandwidth across the board. Also hooking directly into the AM5 CPU socket is a PCIe Gen 4 quad-lane interface that provides 8GB/s of bandwidth for the ASMedia USB 4 controller. USB-wise, there are

further dedicated direct-to-CPU USB interfaces, one USB 3.2 Gen 2 10Gb/s Type-C with support for DisplayPort 2.0 UHBR10 Alt Mode, a single USB 3.2 Gen 2 10Gb/s Type-A with BIOS flash support, and three USB 2.0 USB-A connections.

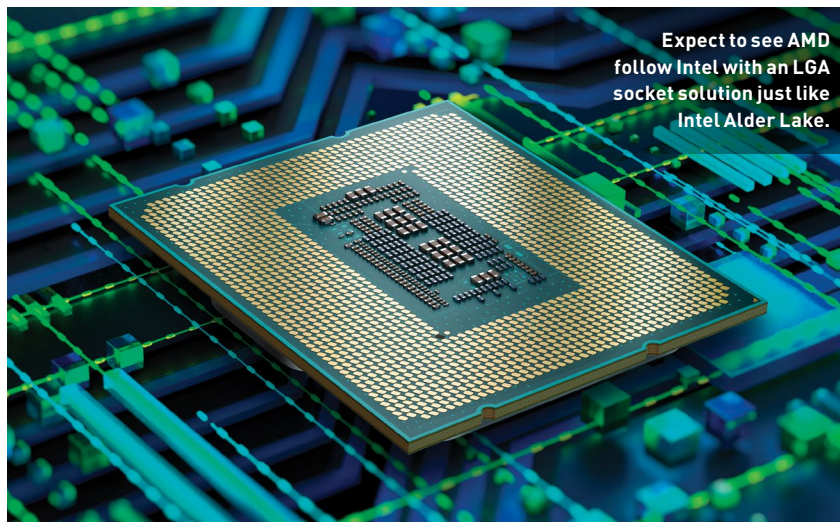
Speaking of display interfaces, all-new Ryzen 7000 CPUs will have integrated graphics, much like Intel's desktop CPUs have had for years. So, AM5 and Ryzen 7000 are fitted with the very latest display connections, including support for both the aforementioned maximum spec DisplayPort 2.0 with UHBR10 support and HDMI 2.1 FRL. You can read more about what those display interfaces enable in the boxout on page 42, but suffice to say, if you want really high resolutions, as well as nose-bleed-inducing refresh rates with HDR enabled, you're going to want some DisplayPort 2.0 action.

Oh, and there's the minor matter of DDR5 memory support. Well, not just support but rather compulsory use thereof. Unlike Intel, AMD tends not to offer support for multiple memory types on the same platform, so DDR5-only it is for AM5. Which is more than fine. Admittedly, DDR5 has been pricey thus far, but costs are now coming down and by the time AM5 becomes a mainstream option, DDR5 could actually be cheaper than DDR4 while offering much more performance. For now, it's not clear how high AM5 and Ryzen 7000 will go at launch in terms of DDR5 memory speed support.

It's also worth noting that AMD has increased the socket TDP power rating from 105W with AM4 to fully 170W for AM5, which is a hefty bump and will allow for some very powerful future CPUs. If that's the AM5 socket-related features covered, what about the chipset? Here,



AMD's Zen 4 Ryzen 7000 CPU will bring a plethora of platform upgrades for AMD fans.



Expect to see AMD follow Intel with an LGA socket solution just like Intel Alder Lake.

AMD is also going outside the box with a novel dual-chip arrangement on its high-end chipsets for the new Ryzen 7000 CPU family.

In simple terms, what AMD is doing is producing a single new motherboard

chip for its new 600 series chipsets, known as PROM21. For the entry-level B650 chipset, a single PROM21 chip is used. But for the premium X670 and X670 Extreme chipsets, you get a pair of PROM21 chips daisy-chained together. It's

a novel solution and will save significant cost compared to tooling up multiple motherboard chips with different feature sets. Each chip is also smaller and built on a more advanced process than those of AMD's 500 series chipsets. So, they use less power, around 7W per chip, and can be run with passive cooling, which again will make for cheaper and more reliable motherboards.

As for the specs of each PROM21 chip, that starts with the PCIe 4.0 x4 uplink to the CPU and two PCIe 4.0 x4 downlink controllers, for a maximum of eight PCIe 4.0 lanes. It also includes a quartet of PCIe 3.0 x1 lanes to enable the four SATA 6Gb/s ports, six USB 3.2 Gen 2 10Gb/s ports, two of which can optionally be fused into a single 20Gb/s port, plus another six USB 2.0 ports. Incidentally, regarding the PCIe-powered SATA ports, the motherboard maker can choose whether to hand some of those lanes over for additional USB bandwidth.

That's a single PROM21 chip and therefore that's what you get with the B650 motherboard chipset. The X670

DDR4 VERSUS DDR5

Is faster memory worth the wallet wallop?

If money's no object, faster memory is always nice. But money is an object and DDR5 memory has proven particularly pricey. Blame the pandemic or any of a number of freak geopolitical events over the past few years, but it does beg the question of whether DDR5 is worth the wallet pain.

It's a particularly pertinent question with Intel's 12th Gen Alder Lake CPUs. How so? Well, Alder Lake rather handily supports both DDR4 and DDR5, so the new memory standard isn't compulsory, as it will be with AMD's new AM5 socket and Ryzen 7000 CPUs later this year. For now and with Alder Lake, DDR5 therefore really has to deliver. Otherwise, why would you pay more? After all, Intel has a poor track record for maintaining long-term socket compatibility. So, it's unlikely if you invest heavily now in Alder Lake and DDR5 you'll be all set for dropping in a new CPU two or three generations down the line. Indeed, we're expecting Intel to break socket compatibility next year with the 14th Gen Meteor Lake processor family.

Alder Lake officially supports DDR4-3200 and DDR5-4800. That looks like a fairly big gap in terms of headline memory speed from the DDR5 option. What's more, in terms of raw bandwidth, DDR5-4800 delivers around 56GB/s, well over 10GB/s more than the DDR4 option. But in actual real-world applications, the benefits aren't always so obvious. In games, all that extra bandwidth doesn't really translate into

better frame rates. In productivity apps such as Photoshop, a five percent boost in performance is about as good as you can expect, while the odd outlier such as Zip compression sees the full force of the bandwidth pay off and a performance boost of about 20 percent.

All of this means DDR5 hasn't been too appealing paired with Intel's Alder Lake CPUs. As for being forced to go with DDR5 when AMD's next-gen platform arrives later this year, the good news is that DDR5 prices are beginning to fall. And as DDR5 moves from early adopter status to mainstream, it will eventually transition to being cheaper than DDR4, thanks to economies of scale. That won't happen in time for the launch of Ryzen 7000, but it shouldn't be too painful to spec up a next-gen AMD rig with a decent amount of DDR5.



Does DDR5 deliver in real-world apps?

and X670 Extreme run a pair of PROM21 chips, so you get double the USB and SATA connectivity. If you're wondering what the difference between the X670 and X670 Extreme will be, well, the Extreme model gets PCIe Gen 5 for both graphics and storage, while the plain X670 will be a case of either-or. It's a slightly artificial distinction, but regressing to PCIe Gen 4 for the graphics, for instance, will likely have zero impact on gaming performance but will make for a slightly cheaper board. At the same time, maximizing PCIe bandwidth for your primary storage device does make sense. All of this means the main appeal of the X670 Extreme will be future-proofing for the day when a 16-

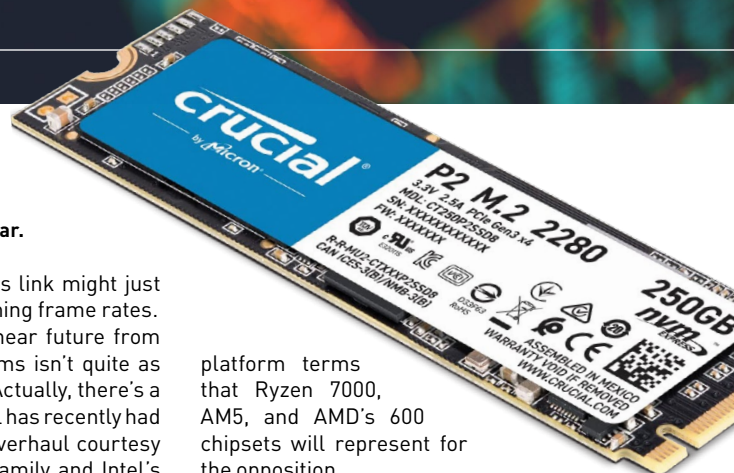
Crucial is working with AMD to have PCIe 5.0 SSDs ready for Ryzen 7000's launch later this year.

lane PCIe Gen 5 graphics link might just make a difference to gaming frame rates.

And so to Intel. The near future from Intel in terms of platforms isn't quite as exciting as that of AMD. Actually, there's a good reason for that. Intel has recently had its own major desktop overhaul courtesy of the Alder Lake CPU family and Intel's 600 series chipsets. We're still expecting a revised CPU family, Raptor Lake, later this year, and 700 series chipsets to go with it. But it won't be the revolution in

platform terms that Ryzen 7000, AM5, and AMD's 600 chipsets will represent for the opposition.

For starters, Raptor Lake will stick with Intel's existing V0 or LGA1700 socket, albeit the fine detail in that area is a little more complicated. LGA 1700



HERTZ SO GOOD

More bandwidth for your monitor

The DisplayPort 2.0 spec was unveiled by VESA in 2019, but it's only now that the first devices are being certified, in part thanks to ye olde pandemic. The big news with DisplayPort 2.0 is more bandwidth. By a very long way. That means support for higher resolution monitors and higher refresh rates, and less need to use compression or lower color depth.

The existing DisplayPort 1.4 interface tops out at 32.4Gb/s of raw bandwidth. But only 25.92Gb/s is usable for image data. With the 2.0 spec, that leaps to a headline figure of 80Gb/s. What's more, the DP 2.0 overhead is much lower thanks to moving from relatively inefficient 8/10b encoding with 20 percent overhead to 128/132b encoding with just 3 percent overhead. So, 77.4Gb/s of that 80Gb/s spec is actually usable and you get three times as much bandwidth as DP 1.4. Nice.

The full speed spec is also known as DP 2.0 UHBR 20, which stands for Ultra High Bitrate and 20Gb/s per lane, making 80Gb/s total with a maximum of four display lanes. There are also UHBR 10 and UHBR 13.5 versions with corresponding bitrates per lane.

In terms of a single monitor, DP 2.0 goes all the way to 15,360x8,460 pixels with HDR at 60Hz and 30 bits of color per pixel, albeit using Display Stream Compression 1.2a, which VESA claims is entirely lossless. In theory, that makes it visually indistinguishable from a non-compressed image. As for the highest resolution support without DSC, that's 10,240x4,320 at 60Hz without HDR at 80Hz and up to 24bpp.

Of course, as well as more pixels, that bandwidth can be used to support higher refresh rates. If, for example, 4K at 240Hz is your bag, you're going to want some DisplayPort 2.0 action. The snag, as ever, is that you're also going to need new hardware. No surprise, that means a new GPU. We're expecting both AMD's upcoming Radeon RX 7000 series GPUs and Nvidia's RTX 4000 series to support DisplayPort 2.0. Funnily enough, however, it will likely be Intel's upcoming Arc graphics cards that will be the first to offer DP 2.0 support. But we've got a feeling you won't want to touch

those with an EM-shielded, fireproof, 10-foot stunt cable, as they are shaping up to be very disappointing by all accounts.

If that's a story for another day, what you might not have bargained for with DisplayPort 2.0 is a special cable. To achieve the full 80Gb/s, DP 2.0 requires an active cable to boost the signal. Fortunately, our understanding is that monitors that require an 80Gb/s link will have a tethered cable or a cable built into the display. So, you probably won't have to pay for it separately. It's also not clear if 80Gb/s support will be on all DP 2.0-compatible graphics cards or if it will be a premium feature. We'll keep our scanners peeled and report back when details are firmed up, but our hunch is that the 80Gb/s interface won't be on all graphics cards.

Meanwhile, if you're wondering about HDMI, for now, there's no news on any updates over the existing 2.1 specifications. DisplayPort 2.0, therefore, will be the weapon of choice for really high-res and high refresh rate computing.



DisplayPort 2.0 will enable future uber-res and refresh rate monitors.

as used by Alder Lake is a 1,800-pin socket but the Alder Lake CPUs only have 1,700 contact pads. For Raptor Lake, it's expected that all 1,800 pins in the V0 socket will be connected. It's quite clever, really, and will allow the 1,800-pin Raptor Lake to be backward compatible with existing 1,700-pin motherboards while increasing pin-out. That said, we don't want to give Intel too much credit for maintaining backward compatibility for a single generation. It's the least it can do to ensure some kind of upgrade path for existing Alder Lake motherboards.

But can you expect any platform upgrades from Raptor Lake and its 700 series chipset? In terms of memory, Intel will increase DDR5 native support from DDR5-4800 to DDR5-5600, which will provide a reasonable bump in terms of memory bandwidth. Our understanding is that the Intel 700 series chipset silicon

is essentially carried over from the 600 series. However, there might still be some unlocking of what you might call hidden features. The latest, admittedly unofficial, information from Intel indicates that the number of chipset PCIe Gen 3 lanes will be reduced from 16 to eight, but the PCIe Gen 4 lane count will go up from 12 to 20. The 700 series is also expected to get one additional USB 3.2 20Gb/s port for a grand total of five.

Of course, what we'd really like to see is a tweak to the CPU socket connectivity for Raptor Lake. While Alder Lake along with the LGA1700 socket and the 600 series chipset was first to market with PCIe Gen 5, that was limited to the 16-lane graphics link, an arguably redundant feature given there are no PCIe 5.0 graphics cards. Meanwhile, the dedicated M.2 storage interface for the CPU socket was a quad-lane PCIe 4.0 link. Not bad,

but not PCIe 5. To be clear, you can run a PCIe 5.0 SSD with Alder Lake. But to do so, you need to use an add-in PCIe card and cut the x16 main graphics link in half to provide access to some PCIe 5.0 lanes. The CPU itself only has those 16 lanes.

The big question, therefore, is whether Raptor Lake will upgrade the direct-to-CPU M.2 interface to Gen 5 spec just as Ryzen 7000, AM5, and AMD's 600 series chipset will deliver. We were hopeful that those additional 100 pads on the bottom of Raptor Lake CPUs were being added at least in part to do just that. Unfortunately, just as we go to press, a leaked internal presentation from Intel shows that the PCIe spec for the Raptor Lake CPU itself is not changing.

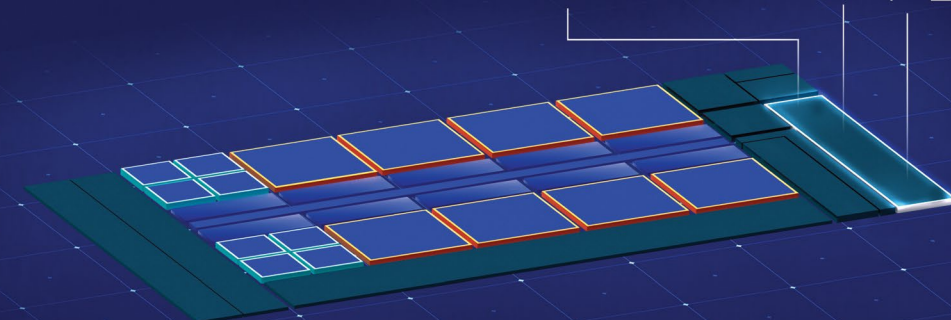
If it does not happen for Raptor this year, then it's pretty much a nailed-on certainty that native PCIe 5.0 storage from Intel will arrive next year with the

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12th Gen Intel® Core™: PCI Express 5

Alder Lake leads the transition to the next generation with PCI Express 5.0. The versatile System-on-Chip architecture mixes multiple PCIe generations to meet the needs of next-gen graphics, high-end storage, ultra-fast networking, and more.

PCIe = Peripheral Component Interconnect Express



Double the bandwidth

PCIe 5.0 primes Alder Lake for the next generation of GPUs. The new standard offers significantly more bandwidth than the previous generation by running individual lanes at twice the speed.

2x
faster than
PCIe 4.0

64GB/s
for 16-lane
desktop slots

Backward compatible

The PCI Express standard is backward compatible with previous generations all the way back to PCIe 1.0. Alder Lake is prepared for the next generation while retaining compatibility with existing hardware.



Intel already has PCIe 5 support, but lacks a dedicated PCIe 5.0 link for storage.



AMD is bringing DDR5 support to the new Ryzen 7000 CPU family later this year.

Meteor Lake CPU family and 800 series chipsets. As for what else will arrive with Meteor Lake in platform capabilities, there's little to no information available. But we'd expect even more by way of DDR5 speeds, more USB connectivity, and hopefully a faster link between the CPU itself and the chipset. One other issue to be aware of with Meteor Lake is that, in typical Intel style, it's expected to break socket compatibility and introduce a new LGA1851 platform. So, Raptor Lake will be the only upgrade path for existing Alder Lake-based rigs.

Of course, all of these fancy new motherboard features aren't much good unless there are devices to plug into them. Here we are primarily thinking of storage and, more specifically, the arrival of PCIe Gen 5 SSDs. A little earlier this year, AMD said that it was working with several key players in the storage industry to make sure that the Ryzen 7000 family of CPUs launched alongside SSDs with next-gen PCIe 5.0 interfaces.

AMD reckons that Crucial and parent company Micron will have a PCIe 5.0 drive ready for the Ryzen 7000 launch, which is intriguing given that Crucial hasn't historically been quick to support new PCIe standards. AMD says Gigabyte, MSI, Corsair, and many others will follow shortly thereafter. As for what kind of performance you can expect from PCIe 5.0 SSDs, well, the new protocol allows for a theoretical doubling of performance up to 16GB/s. As ever, protocol overheads reduce that in practice.

With PCIe 4.0, the fastest drives manage around 7.3GB/s peak sequential

performance compared to a maximum theoretical speed of 8GB/s. Early performance figures from SSD makers, including Adata, previewing future PCIe 5.0 models indicate that first-generation PCIe 5.0 SSD read speeds will top out at around 14GB/s, with writes nearer 12GB/s. That is serious, face-melting storage performance.

The slight snag is that the increased PCIe bandwidth will do nothing to improve the current Achilles heel of flash-based SSD performance, namely 4K IOPs (or input-output) performance. That's limited by the inherent characteristics of flash memory and the capability of existing SSD controller chipsets. The 4K random access performance of even the fastest flash SSDs is measured in a few hundred MB/s rather than GB/s. However, when new SSD controller chipsets have delivered support for the latest PCIe standard in the past, IOPs performance has tended to take a step forward, too. So, here's hoping for a particularly big one when PCIe 5.0 SSDs arrive later this year.

Speaking of improving storage IOPs performance, something we're hoping will make an impact even with existing SSDs in the near future is DirectStorage from Microsoft. It's been available on Microsoft's Xbox games consoles since the launch of the latest Series S and X models. Strictly speaking, it was released for the PC in March this year and so is already available. But its roll-out has been limited so far for PC gaming.

Anyway, the existing issue for games in terms of storage performance involves that perennial IOPs problem. In order

to efficiently load only the data actually required for a given game level, such as textures and models, rather than just loading everything available in one big chunk, the data is broken up into lots of tiny packets. This reduces the amount of data that's loaded into the GPU's memory buffers but increases the IOPs load on the SSD.

The Windows OS storage API isn't terribly well optimized for getting the most out of the latest NVMe SSDs when it comes to high IOPs workloads. The existing API incurs numerous extra steps between an application making an IO request and the request being fulfilled by the storage device, resulting in unnecessary request overhead. However, these steps aren't required for every IO request on every NVMe drive on every gaming machine. With a supported NVMe drive and a properly configured gaming machine, DirectStorage will be able to detect up front where these extra steps are not required.

Microsoft says DirectStorage will also reduce per-request NVMe overhead and enable batched many-at-a-time parallel IO requests, which can be efficiently fed



Imagine if Alienware's awesome OLED panel could power a gaming laptop via USB-C....

© CORSAIR, ALIENWARE, INTEL



Intel's imminent Arc GPUs are likely to be the first to support the new DisplayPort 2.0 interface. Just don't mention the frame rates....

to the GPU, and give games finer grain control over when they get notified of IO request completion instead of having to react to every tiny IO completion. Exactly

how much impact this will actually have on load times, however, isn't yet clear.

At this year's Games Developer Conference (GDC), the developer of the

upcoming action role-playing game *Forspoken*, Luminous Productions, claimed that DirectStorage would allow game level loads as fast as one second. During the event, the quickest game level load time it demoed was 1.7 seconds, while the same level loaded in around 2.5 seconds running on the standard Windows storage API. So, the benefits aren't as yet hugely dramatic. But we suspect that once game devs really get their heads around DirectStorage, lengthy game-load times will be a thing of the past.

All told, then, the big story for the PC over the next few years is going to be bandwidth. Everything from storage to the CPU socket and display connectors is going to be bursting with the stuff. And that is rather handy. Remember those hot new CPUs and GPUs we mentioned right back at the beginning? Those puppies are going to take some serious feeding. Happily, the PC platform should be well up to the task. ☺



USB 4 AND SO MUCH MORE

At last, a naming scheme mere mortals can understand

Increasing the features and bandwidth on offer from the fantastically successful and useful USB, or Universal Serial Bus, interface is always welcome. But for the love of everything that's holy, USB's nomenclature needs an overhaul, too. How on earth anyone thought names like "USB 3.2 Gen 2x2" are a good idea for a consumer-focused connector is a complete mystery. Indeed, why anyone thought changing the name of USB 3.1, which was fairly comprehensible, to "USB 3.2 Gen 2" was an improvement is even more baffling.

Enter, thank goodness, USB 4, an opportunity to not only increase speed and features but also sort out the idiotic branding. For starters, USB 4 doubles maximum throughput to 40Gb/s. It also simplifies the naming scheme. There will be two versions of USB 4, known as USB 4 20 and USB 4 40, the final numeral indicating the peak bandwidth on offer in Gb/s. Both versions will

use the existing USB-C physical connector.

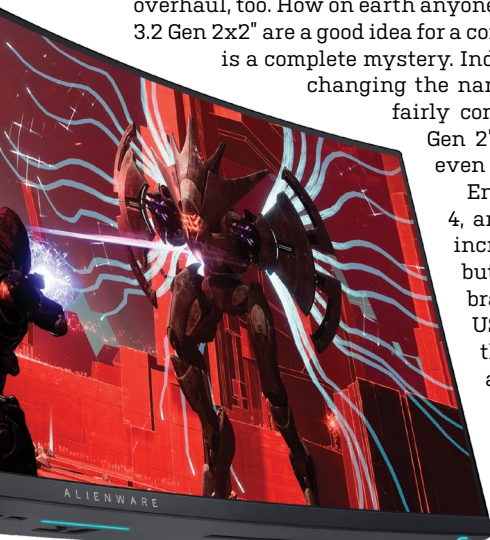
What's more, in an uncharacteristically magnanimous move, Intel essentially handed over all its work on

Thunderbolt 3 to the USB Promoter Group, the industry body that defines the USB interface. Long story short, USB 4 incorporates full Thunderbolt 3 functionality and support, and does so without the need to pay any royalties to Intel.

Along with the introduction of USB 4, another imminent USB-related upgrade involves the USB Type-C physical interface specifically. Existing USB-C interfaces are capable of power delivery in parallel to the data connection. The most obvious upside is the ability to connect a laptop to a monitor and have the former charge the latter while the latter drives the image on the former. Once you've gone USB-C with your laptop, you'll never want to go back to a multi-cable solution. It's just so slick.

Currently, USB-C power delivery maxes out at 100W. That's fine for a thin and light, and just maybe for some mid-tier performance laptops. But it's not nearly enough for a beefy gaming laptop with a multicore CPU and a phat GPU. Happily, USB Type-C revision 2.1 fixes that. It ups power delivery support to fully 240W, which should be enough for all but the biggest portable gaming bricks.

There are, however, a couple of catches. Firstly, that 240W spec requires a special cable known as the Extended Power Range cable. These cables will have an identifying emarker and be clearly marked as 50V and 5A capable. So, you won't be able to use any old USB-C cable, which is a pity. The other snag is that 240W is a big old power requirement and it won't be cheap or simple to integrate that into a monitor. Our expectation is that 240W-capable monitors will be both scarce and very expensive.



CENTERFOLD

Alienware Aurora R13

ALIENWARE once dominated the desktop gaming PC market with its unique cases, but now everyone from Razer to HP has distinctive-looking designs. The Alienware Aurora R13, available in both black and white, is a return to machines with the wow factor, thanks to its compact form, glass window, and aesthetically pleasing curves. The only people with cause to complain are those used to balancing their cup of coffee on top of their PC, as it will sadly slide right off.

The body of the machine isn't its only unique feature; the bespoke motherboard sits between microATX and ATX in terms of size. Regarding components, our sample features the best of the best pretty much across the board: Intel Core i9 12900KF CPU, 64GB of DDR5 RAM, and Alienware Cryo-Tech liquid cooling. Only the RTX 3080 GPU lets the side down at this price point, but Alienware has wrung every last drop of performance out of it, to the point where it is a close match for a 3090-powered HP Omen at 1400p and 4K. You can also choose to upgrade the GPU when purchasing.

That glass panel gives you a clear view inside this compact system, most of which is user-upgradable. The GPU, memory, and 1TB SSD are all accessible—it's just the 750W power supply and the motherboard that would be tricky to replace.

Of course, this being an Alienware rig, you're paying for that high performance and sleek look, with this configuration costing around \$3,400. While that's pricey, we were surprised at how well the machine is configured for performance, not far off our favorite compact desktop, the Corsair One i300, which costs \$5,000. —GUY COCKER





1 INTERNALS

This is a compact motherboard that's completely unique in terms of dimensions. Alienware's own bare design on its generic motherboard, RAM, and GPU leaves a little to be desired next to the beautiful internals of other boutique builders, but you have to be impressed with the clean overall look. There's also Alienware FX lighting, which can be customized through software.

2 PERFORMANCE

You'd hope a pre-built system would perform well out of the box, and it's here the Alienware stuns. We were astonished by how well-tuned this is, cranking out fantastic performance in 4K and 1440p gaming with no user tweaks required. Of course, it can get hot in such a small chassis and the fans have a tendency to whirr up under load, but this offers excellent bang for your buck.

3 CONNECTIVITY

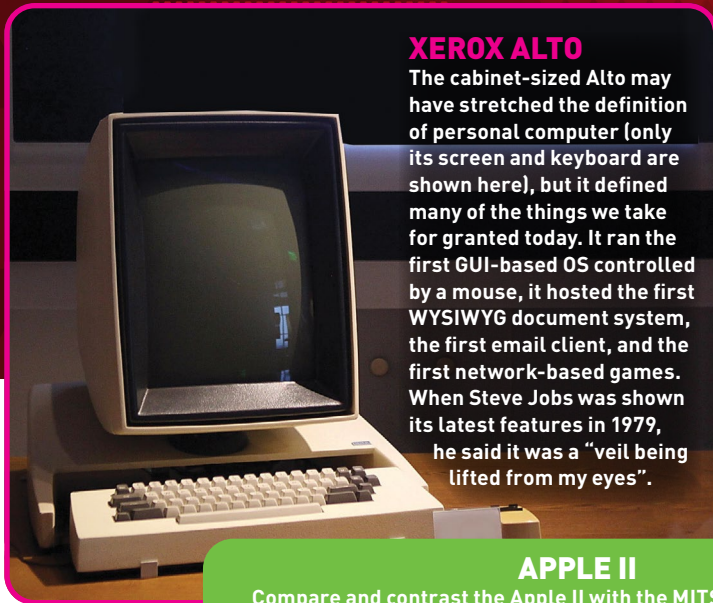
Given the machine's compact form, this isn't the most abundantly generous machine when it comes to ports, but you still have plenty of options. There are nine USB ports and three USB-C ports spread across the front and rear of the machine, which should be enough for most people, plus a handy 3.5mm headset port on the front. There's only one Ethernet port, although it's thankfully 2.5Gb/s.

THE WORLD'S MOST ICONIC PCs

What do we mean by iconic? Here, we're talking about the influencers. The computers that changed perceptions of what computers could be, or inspired a new type of design

CONTRIBUTORS: Barry Collins, Tim Danton





XEROX ALTO

The cabinet-sized Alto may have stretched the definition of personal computer (only its screen and keyboard are shown here), but it defined many of the things we take for granted today. It ran the first GUI-based OS controlled by a mouse, it hosted the first WYSIWYG document system, the first email client, and the first network-based games. When Steve Jobs was shown its latest features in 1979, he said it was a “veil being lifted from my eyes”.



COMMODORE PET

A computer so iconic that it can be recognized by its silhouette, the PET was Commodore’s first computer—built to take advantage of the company’s own 6502 processor (also used in the Apple II). At that point, Commodore was famous for its calculators and typewriters, and its legendary boss Jack Tramiel took some persuading that newfangled computers were worth a gamble. But thanks to Chuck Peddle, the chip’s lead designer, Tramiel rolled the dice—and a long line of Commodore computers was born.

APPLE II

Compare and contrast the Apple II with the MITS Altair 8800 below. Only three years separated them, yet the Apple II looked stylish—by contemporary standards, at least—and still included all the expansion slots demanded by the enthusiasts expected to buy it. Plus, astonishingly for the time, it could output in color. What was a trickle of sales in the Apple II’s first year (a few thousand) soon turned into a flood of millions, helped by the arrival of VisiCalc, the first spreadsheet program, and numerous iterative improvements to the hardware.



MITS ALTAIR 8800

Although it looks more like a prop from a bad 1970s sci-fi movie, the Altair 8800 was the first minicomputer kit. It came in various configurations, but the base spec included a 1,024-byte memory board and Intel’s 8080 processor. Fripperies such as a keyboard or display weren’t included. It caught the eye of a keen Harvard student called Bill Gates, who wanted to create a BASIC interpreter for the 8800 and worked part-time for the company, before starting a small firm of his own...



SINCLAIR ZX80

On May 2nd, 1979, Alan Mayne wrote in *The Financial Times* that personal computers “could drop to around £100 within five years”. He was only out by a factor of 10 or so, with Clive Sinclair announcing the ZX80 in January 1980. You could buy it fully assembled for £100 (\$200), or build it yourself from a cheaper kit form. While the membrane keyboard had its issues and the 1K of memory was positively tiny, this cheap computer paved the way for computers in homes.

1973

1974

1977

1977

1980



IBM PERSONAL COMPUTER 5150

"Welcome IBM. Seriously." That was Apple's response, via a full-page ad in *The Wall Street Journal*, to IBM's first personal computer in August 1981. It marked a departure for IBM, which had built its post-war reputation on mainframes and minicomputers. IBM's chairman Frank Cary was persuaded by Bill Lowe—"the father of the IBM PC"—that he could not only create a profitable new product line but build it from scratch in a year. With the help of a certain Bill Gates, who kept the rights of the OS to himself, the rest is history.



COMMODORE 64

For millions of schoolchildren in the 1980s, the C64 was their introduction to computers. Despite its physical similarity to the VIC-20, this was much more flexible. There was the 64KB of memory, compared to the 48KB typical of its rivals, but also sprites to make games slicker—plus a revolutionary sound chip. All this for \$595. Where the IBM PC legitimized the market for business computers, the C64 did exactly the same for home computers.



OSBORNE 1

Wikipedia describes the Osborne 1 as "the first commercially successful portable computer." Given it weighed 24lb, the word "portable" is doing a lot of heavy lifting. Nevertheless, the Osborne—brainchild of computer book publisher Adam—sold in droves, with its 4MHz processor, dual 5.25-inch floppy drives, and 5-inch CRT display winning admirers. At its peak, it was shifting 10,000 units per month.



COMMODORE VIC-20

Often consigned to the footnotes of history, the VIC-20 was actually the first computer to sell a million units, and introduced many people to programming, thanks to its detailed manual. And eking all they could from the miserly 1.5KB of memory. Perhaps most crucially, it proved to the Commodore board that there was a home market to be attacked along with the businesses that had embraced the PET. Next stop, the Commodore 64...

BBC MICRO

Realizing the importance of computers, in the early 1980s the BBC commissioned not only a TV series on computer literacy but its own computer and BASIC. That way, people could follow its programs with confidence rather than rely on someone else's hardware and software. It wisely chose Cambridge's Acorn Computers to partner with, and it wasn't long before a BBC Micro was in every school in Britain.



1980

1981

1981

1981

1982



EPSON HX-20

Several computers have claimed the “world’s first laptop” crown, among them the Epson HX-20. Whether a computer with a screen that spans a mere four lines of 20 characters can be classed as a laptop is debatable, but it’s impressive that it includes a tiny printer next to the display, albeit one that sounds and behaves more like a checkout register. Nevertheless, that Epson packed this all into a 3.5lb unit is impressive for the time, not least because it could run for hours on four AA batteries.



AMSTRAD CPC 464

Anyone who’s seen the British version of *The Apprentice* knows that Alan Sugar is easily riled, and in 1983 his ire was directed at Sinclair. If nerds like Sir Clive could make money from computers, so could he. And he’d do it by delivering a complete system that didn’t need to be plugged into a TV. The small matter of creating it fell mostly on Roland Perry, who—in best *A-Team* style—set about creating an ace collection of programmers and electrical engineers. His plan came together, with the CPC 464 selling millions of units over its six-year life.

COMPAQ PORTABLE

The Compaq Portable stretched the definition of the word: It weighed 28lb, ten times heavier than today’s MacBook Air. However, this was 1983, and a computer that could be lugged around like a small suitcase was a minor miracle. The Portable had a nine-inch green screen, 128KB of RAM, and could accommodate two 360KB disk drives. It didn’t have a battery, so much like a portable TV, you had to plug it into the wall. But despite these shortcomings, this IBM-compatible was a big hit at the time.



SINCLAIR ZX SPECTRUM

The ZX Spectrum’s rubber keys were about as useful as super-gluing your fingers together when it came to typing, but we can forgive almost all of the dinky Speccy’s flaws. It was a ridiculously cheap introduction to home computing, with the 16K model costing \$200. Yes, the limited colors bled into one another; yes, you needed to plug in an external tape cassette to load games; yes, the sound was comparable to a faulty dishwasher—but it was the 1980s and everything was trash.

APPLE MACINTOSH

Having been kicked off the Apple Lisa project, the Mac turned Steve Jobs’ fortunes around. Leading a small but talented team, his obsessive attention to detail and sheer charisma helped create a truly revolutionary computer. Complete with a graphical user interface and a one-button mouse, it was easy to get along with—if you had \$2,495 to spare. When Jobs introduced the Macintosh, he allowed the computer to speak for itself, thrilling the crowd of Apple shareholders. It took a while for the Mac to live up to everyone’s heightened expectations—disappointing first-year sales, due in part to the paltry 128KB of RAM in those first models, led Jobs to leave Apple and start NeXT—but the Macintosh is arguably the most iconic and influential computer ever made.



1982

1982

1983

1984

1984



AMSTRAD PCW

The Amstrad PCW was no oil painting, but it was a bargain. \$799 wasn't pocket money in 1985 (worth around \$2,600 today), but for that, you got the PCW, a printer, word-processing software, and a bunch of utilities. By comparison, the Apple Macintosh launched a year earlier costing \$2,500. It had its idiosyncrasies—the use of 3-inch rather than 3.5-inch floppies for one—but the PCW sold in its millions to a generation seeking affordable computing.

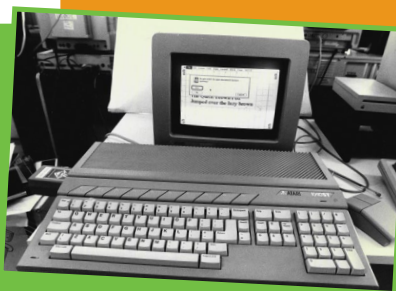


TOSHIBA LIBRETTO

A decade before netbooks, Toshiba's Libretto defined the compact laptop. The size of a hardback book, it slotted between the PDA and laptop market of the time. The Libretto range was more popular in the Far East, with several models only released in Japan. To squeeze a full-blown laptop into a device weighing less than 2lb was some feat at the time, even if the 6.1-inch screen now seems almost quaint.

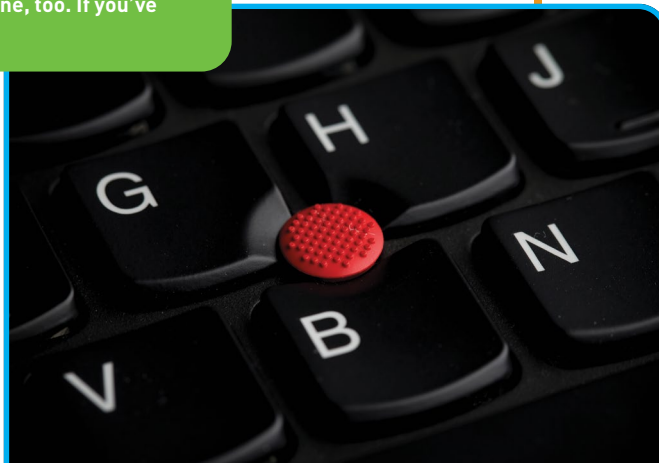
ATARI ST

Amiga or Atari ST: Which horse did you back? The ST was one of the great PCs of the pre-Windows era and found a niche in several industries. Its built-in MIDI ports made it popular with musicians—Cubase and Logic Pro both started life on the Atari ST, and Fatboy Slim recorded his *You've Come A Long Way, Baby* album on one, all stored on floppy disks. It was a home gaming machine, too. If you've never played *Kick Off 2* on an ST, you haven't lived.



COMMODORE AMIGA

The Amiga may have arrived in the mid-'80s, but it didn't become a mainstay of back bedrooms until the 500, 600, and (Dad got a promotion, did he?) 1200 arrived in the early '90s. These beige beauties dominated the home computing landscape until Commodore ran into financial woes in the late '90s. Readers of a certain age will remember boxes full of ripped-off games on floppies, wrestling with Workbench, and wobbling their Powerplay Cruiser joystick into the port.



IBM THINKPAD

The distinctive ThinkPad has been an unmistakable mainstay of the laptop market ever since it arrived in the early 1990s. That iconic red trackpoint in the middle of the keyboard remains a must-have for many buyers, even in the age of super-smooth trackpads the size of swimming pools. ThinkPad keyboards have always been top-notch, even after the range was sold to Lenovo. And who can forget that slide-out Butterfly keyboard on 1995's ThinkPad 701?

1985

1985

1985

1992

1996



APPLE IMAC G3

Without the original iMac, none of the other Macs on this list would have been made. This was the computer that saved a company, arguably the most iconic PC of them all, with its transparent plastic casing. The iMac wasn't only a design classic, it was a boundary pusher. It propelled floppy disks into landfill, for example, and helped to standardize the USB port.

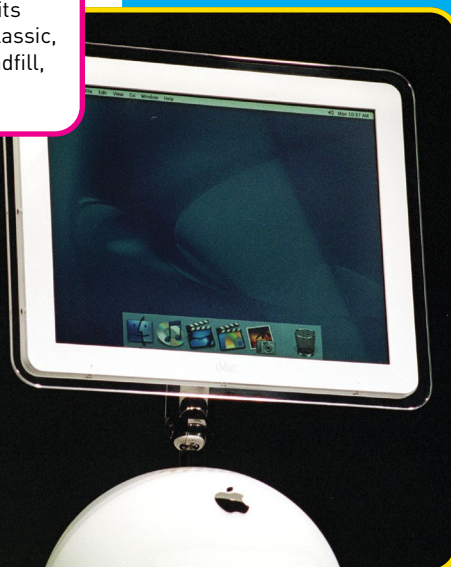


APPLE MACBOOK PRO

The MacBook Pro has not only set the standard for pro-grade laptops for over 15 years, but it has also been the vehicle for a series of Apple innovations. It was the first laptop to include a MagSafe connector, preventing laptops from being yanked off desks when a foot got tangled in the power cord—an innovation that Apple recently reintroduced on the M1 MacBook Pro. It was also the first to incorporate the unibody design that's now commonplace, as well as the less successful Touchbar.

APPLE IMAC G4

It's 20 years since the iMac G4 launched, yet it still looks like something from the future. The domed base contained all the computing power, while the arm allowed the screen to be positioned at almost any angle. The 15-inch screen looks tiny now, although there was a widescreen 20-inch version. The G4 was the mainstay of reception desks in fashionable London offices for a few years, before it was discontinued abruptly in 2004.



ALIENWARE AREA 51 PREDATOR 1

If a gaming PC isn't a riot of RGB lighting these days, we're disappointed. In 2003, however, PC cases were a lot more mundane, which made the Alienware Area 51 an icon. Looking like a prop from *Alien*, the rounded lime green case was fitted with the kind of grilles you'd normally find on a Porsche. The internals were equally punchy, but the fact those cases are still changing hands on eBay tells you all you need to know about the design. Little wonder that boring, corporate Dell bought the brand in 2006.



ASUS EEE PC

There was a time when cheap, tiny laptops were all the rage. In the pre-tablet, nascent-smartphone age, buyers couldn't get enough of netbooks as cheap ways to get on the internet. The Eee PC wasn't much to look at, and buyers soon tired of netbooks' sluggish performance, cramped keyboards, and small screens, but for a couple of years, netbooks flew off the shelves, and the Asus Eee PC had set the ball rolling.

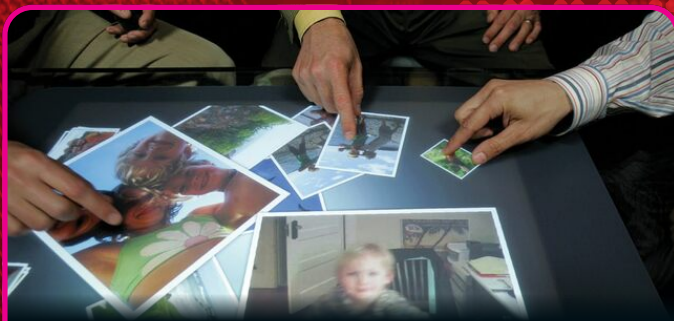
1998

2002

2003

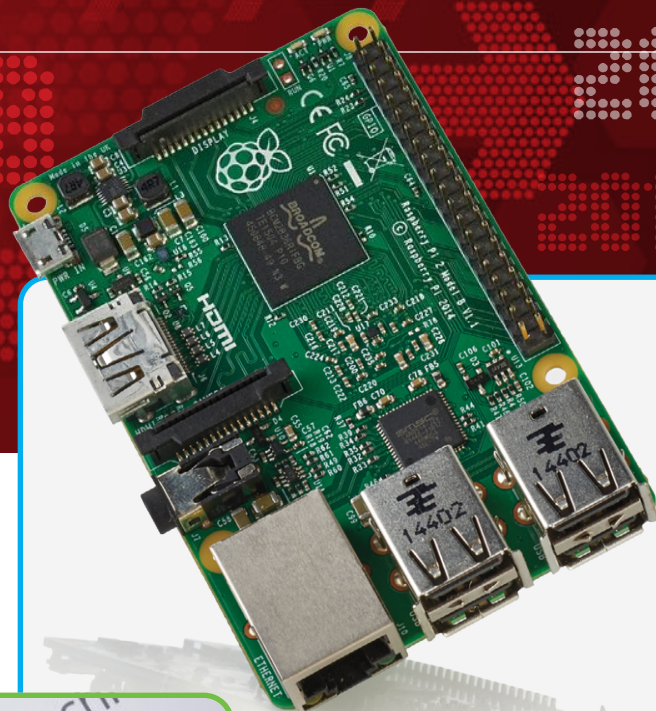
2006

2007



MICROSOFT SURFACE TABLE

Microsoft's first Surface wasn't a tablet, it was a table. A \$10,000 cabinet-sized slice of the future, or so Redmond wanted us to believe. It was an astounding piece of technology when touchscreens were still novel, but it never found its *raison d'être*. Still, it blazed a path for future touchscreen initiatives, even if we aren't sorting our digital photos by swiping through a 'puddle' of shots on our 200lb coffee tables.



RASPBERRY PI

Unlike many of the iconic computers here, the Raspberry Pi was no looker. But that didn't stop you from buying one or more of those little green boards, did it? Partly that's down to its price—a computer for \$35 is too good to ignore. The Pi's sheer flexibility has seen it become the darling of coders, hobbyists, and tinkerers all over the world. And for the Brits, it was an echo of that 1980s micro era that got many people involved with computers in the first place.

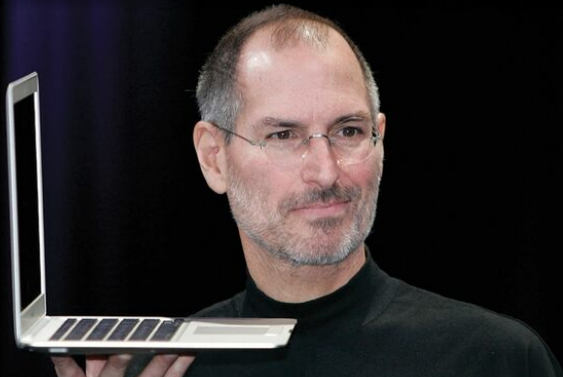
SAMSUNG CHROMEBOOK

In 2011, Google proudly announced the arrival of a revolutionary new type of laptop: the Chromebook. Acer and Samsung both launched products in June, but it was with more of a fizzle than a bang. Early Chromebooks were criticized for being slow, and it took a couple of iterations before they started to gain traction—in schools, in particular. In 2021, Chromebooks outsold MacBooks. Now, Google is making a push into the business world on the basis that its secure, long-lasting, and always-up-to-date Chromebooks are perfect for people who have to work anywhere.



APPLE MACBOOK AIR

When Steve Jobs took the first-ever MacBook Air out of a manila envelope in 2008, Apple had changed the computer industry once more. Even at its thickest point, the MacBook Air was thinner than even the slimmest Windows competitor, the Sony TZ series, as Jobs pointed out with a scarcely concealed smirk. It's a design that's served Apple for well over a decade and still doesn't look the least bit dated.



DELL XPS 13

The moment we saw the XPS 13 in 2012, we knew a Rubicon had been crossed. This, at last, was a Windows laptop with enough style to rival Apple. But it wasn't trying to mimic its rival but do something on its own, squeezing a 13.3-inch panel into a chassis the size of a 12-inch laptop. With an SSD and one of Intel's fancy new Core processors, plus a screen protected by Gorilla Glass, the only downside was its price.

2008

2008

2011

2012

2012



LENOVO YOGA

Windows 8 had its problems, but one of the best things it did was inspire a range of new form factors. None in that era was better than the Lenovo Yoga, named for its ability to flap and fold into a variety of configurations. It folded flat against its base to form a (chunky) tablet; it could be stood in tent mode for watching movies, or it could be used as a conventional laptop. The Yoga brand lives on, proving that this most flexible of laptop designs had iconic staying power.

GOOGLE PIXELBOOK

Google doesn't have much of a hardware pedigree, but the Pixelbook remains the best Chromebook ever. Its 2400x1600 display still looks sharp, and the 3:2 aspect ratio was a welcome, sensible change at a time when widescreen laptops were in vogue. However, the standout feature of the Pixelbook was its keyboard: Soft yet perfectly responsive, it's still one of the best keyboards we've seen on a laptop. The Pixelbook was a premium piece of hardware in a sea of cheap plastic rivals.



MICROSOFT SURFACE

Some argue that the Microsoft Surface isn't iconic. That it hasn't had an effect on computer design since the ill-fated Surface RT in 2012. But we have one eye on the future when we say that its kickstand-based approach and detachable keyboard marked a radical departure from the conventional clamshell laptop and may yet become the dominant design for mobile computers. Or may not. At least Microsoft dared to do something different.



APPLE iMAC M1

The iMac wasn't the first Mac to benefit from the M1 processor but it was the first M1 machine to get a significant redesign. Stupendously slender, it looks like a massive iPad on an angled frame. In a call back to the first iMacs, it comes in a range of colors. Being M1-based, it's fiercely powerful without making a sound. It's elegance in electronic form.



THE NEAR-ICONS

ACORNATOM (1980)

The Atom was the predecessor to the BBC Micro, and with 2022 goggles on, looked much more stylish than its successor.



Neat fact: The manual for the computer was called *Atomic Theory and Practice*.

DRAGON 32 (1982)

We love the story of the Dragon 32—a Welsh toy company deciding to build a computer was so mid-1980s—but it was really just a copy of the Tandy TRS-80.



ACORNELECTRON (1983)

Acorn's attempt to build a cut-down BBC Micro was beset with difficulty, leading to long delays. By the time it was available, the demand had gone.



SINCLAIR QL (1984)

This could have been the British Mac, based around a 16-bit Motorola processor, and with a brilliant multitasking OS. Plus a full suite of office software. But poor build quality and delays ultimately strangled the QL at birth.



ACORN ARCHIMEDES (1987)

Not iconic in terms of looks, but this was the first ARM-based computer—admittedly, it's taken the world some time to catch up. It went on to be a stalwart in schools for the next decade.



APPLE POWERBOOK (1991)

The predecessor to the MacBook Pro laid the foundations for Apple laptops. Thank the silicon gods that the trackball embedded beneath the keyboard was one of Apple's lesser-copied innovations.



PSION SERIES 5 (1997)

Yes, yes, yes, the Series 5 was a PDA, but "The World's Most Iconic PDAs" would be a short feature, so it earns an honorable mention here for that brilliant sliding clamshell design and the best mobile keyboard ever.



SONY VAIO X505 (2003)

Before the MacBook Air, there was the VAIO X505—a ridiculously slender laptop, given the components of the time. It was only 0.38 inches at its thinnest point, although the front-loaded keyboard was an acquired taste.

2012

2012

2017

2021

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FUTURE



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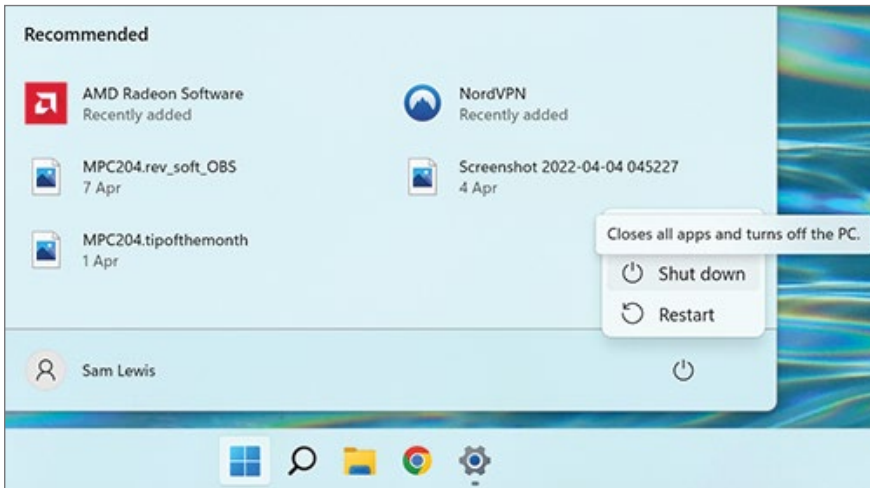
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HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

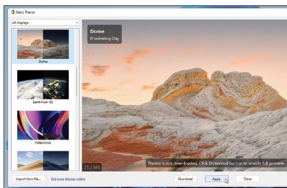
TIP OF THE MONTH



FULLY SHUT DOWN YOUR PC

The Windows Fast Startup feature is enabled by default, which means that when you shut down your PC, it doesn't fully switch off the entire system. Although we love a quick bootup, sometimes you need to close everything down completely. So, next time you want to shut down your computer properly, hold Shift while you click 'Shut down'. This should help sort out minor issues with applications not responding and so on.

MAKE – USE – CREATE



58
Discover how to customize your Win 11 desktop



64
Design your own word art logos with GIMP



66
Build a DIY rig inside a Teenage Engineering case



SAM LEWIS
STAFF WRITER

A MOVING STORY

By the time your eyes hit this page, I should have moved house. As exciting as this is, I have acquired a colossal arsenal of tech gear since joining the *Maximum PC* team and it isn't going to be easy to dismantle my current setup.

However, the move gives me chance to really go to town on my next one. I still have a liquid-cooled PC with an Intel i9-12900K and Asus RTX 3080, so that's the system well and truly checked, but I need a new monitor to pair with it. I currently have an ultrawide screen with a 60Hz refresh rate, which you could say is hindering my gaming capabilities slightly.

First-world problems parked, this new place will be a great opportunity to build a unique space for both work and play. So, I've put *Elden Ring* to one side and managed to steer clear of spoilers so I can experience it properly in a new setup. For now, I'm living out of suitcases and the Razer Blade 14 has made its way to the top of my friends' list. Though it is more than capable of playing *Elden Ring*, I want to experience the game in all its glory on a desktop.

I have, however, been playing *Warzone* again as I can hop on from time to time. Saying that, each time I leave it for a few weeks I swear the skill level of other players grows hugely, or am I just terrible? Probably the latter...

submit your How To project idea to: editor@maximumpc.com

Customize Your Windows 11 Desktop

YOU'LL NEED THIS RAINMETER

Download this free tool from
www.rainmeter.net.

CAIRO

Visit <https://cairoshell.com> to
download this handy app.

WINDYNAMIC DESKTOP

Grab this gratis tool from
<https://github.com/t1m0thyj/WinDynamicDesktop>.

ARE YOU BORED with your Windows desktop? Perhaps the new Windows 11 refresh doesn't quite grab you, or maybe you've decided to cut loose after years of making do with various shades of gray. The good news is that your desktop doesn't have to remain staid and stale, and we've got all the tips and techniques you need to not only make it more attractive but more functional, too.

We open with a simple facelift using Windows' own tools—a wallpaper change, a color scheme update, and a look at combining all your customizations into a single theme. Not radical enough? Check out the box on page 60 for a tool that can transform your desktop into something more dynamic, with a background image that magically updates as the sun rises, sets, and finally disappears behind the horizon.

If aesthetics aren't your thing, we also introduce you to a desktop "skinning" tool called Rainmeter, which enables you to place a series of useful information tools—from clocks and to-do lists to system resource meters—on your desktop. And last, but by no means least, we introduce you to an even more radical tool, Cairo, which helps you change the way you use your desktop, transforming it into a tool that's as practical as it's pretty. —NICK PEERS



1 SIMPLE TWEAKS

If you're just starting out in the world of desktop customization, you'll find Windows offers many options within its own Settings app—right-click the desktop and choose "Personalize" to see what's available. You're shown a list of themes, which are a collection of wallpapers, color schemes, sounds, and cursors. More on that in step two.

» For now, focus on the sections below these, starting with "Background". Select this and you can set your wallpaper one of four ways using the drop-down: Picture, Solid color, Slideshow (choose a folder of images on your PC), or Windows spotlight, which displays a series of landscapes handpicked by Microsoft.

» By default, when you select a new background, you should find your Taskbar and other desktop elements change color to match the wallpaper—to change this behavior, select "Colors" instead. You'll see options to switch between dark and light mode (Windows enables you to specify different settings for Windows dialogs and apps). You'll also see a "Transparency effects" switch—flick this on and when your dialogs pass over a strongly colored background (such as your wallpaper), you'll see a hint of that color peeping through.

» Beneath this is the "Accent colors" switch—if it's set to "Automatic," the basic colors of dialog boxes, the Taskbar, and other Windows elements are determined by the color scheme of your desktop wallpaper. If you'd rather set these yourself, set the drop-down menu to "Manual" and experiment with the various

colors displayed beneath (if they don't fit the bill, scroll further down, and click "View colors" to choose from the entire Windows palette).

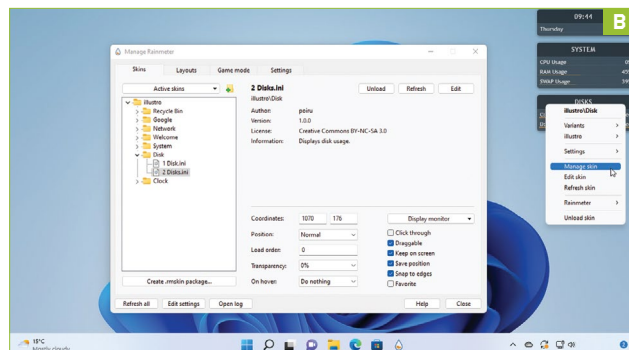
» One final tip: If you want to change the color of the Taskbar, you need to switch from Light mode to Dark or Custom. Once done, the "Show accent color on Start and Taskbar" switch becomes available, and it reflects the other dialogs.

2 WORK WITH THEMES

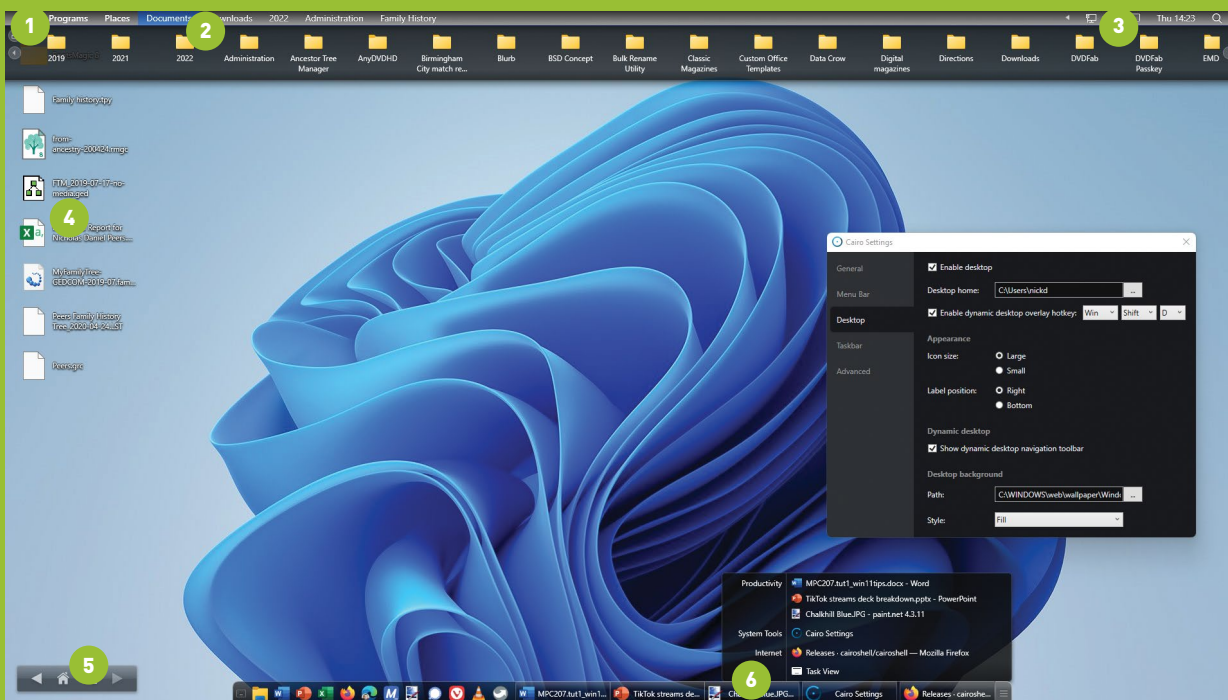
If you're short of inspiration for your new-look desktop, let Windows take the strain by choosing a pre-set theme. You'll see a small collection on the main "Personalization" page—click one and your wallpaper and color scheme should update automatically to reflect the new theme.

» To access additional themes as well as controls for creating your own, click "Themes" followed by "Browse themes" to find other themes to try. These are installed through the Windows Store and you can find dozens of alternatives online. Click "Get," wait for a theme to be downloaded and installed, and click "Open" to return to the "Themes" section of Settings, where the new theme should be available in the list.

» If you'd like to go further, why not craft your own desktop theme from scratch? At the top of the "Themes"



CAIRO IN ACTION



1. CAIRO MENU

Click here to open Cairo's main menu, where you can configure Cairo, access system settings, and shut down Cairo (or your PC).

2. STACKS

Contains shortcuts to Programs (separated into customizable categories), Places (shortcuts to key user

folders such as "This PC"), and Folder Stacks, frequently accessed folders you add by dragging to the bar.

3. NOTIFICATION AREA

Cairo moves the Taskbar notification area to the menu bar, where it resides with a handy Search tool that can be used to search files, folders, system settings, and more.

4. DYNAMIC DESKTOP

Your desktop becomes—in Cairo's words—an "interactive file browser." Simply double-click a folder to view its contents directly on the desktop itself.

5. NAVIGATION TOOLBAR

This floating toolbar enables you to move between folders, jump to a new folder, and

return to your designated home folder.

6. CAIRO TASKBAR

Cairo's Taskbar is a more focused version of Windows' own. Next to the Quick Launch area, open windows are sorted by category. Click the Task List button for a categorized list and access to Windows' own Task View.

dialog, you'll find four shortcuts to each component—click these in turn to make your choices, then return to this screen to click "Save," and give your theme a name. It then appears in the list, ready for selection.

» If you're looking to apply more radical customizations to your desktop's look and feel, you need a program such as WindowBlinds (\$9.99 after a 30-day trial, www.stardock.com/products/windowblinds/). This gives you more control over the appearance of elements such as the Start menu, Taskbar, dialog boxes, and more.

3 RAINMETER

Is your desktop working hard enough for you? If the answer is no, Rainmeter (www.rainmeter.net) could provide the answer. This popular and well-established open-source tool basically enables you to "skin" your desktop by overlaying customizable widgets on top of it. These widgets can display all kinds of useful information, and some are even interactive—for example, a widget enables you to search Google directly from your desktop. Somewhat confusingly, Rainmeter describes its widgets as "skins", and collections of widgets as

"suites". For the purposes of clarity, we're sticking with widgets and skins.

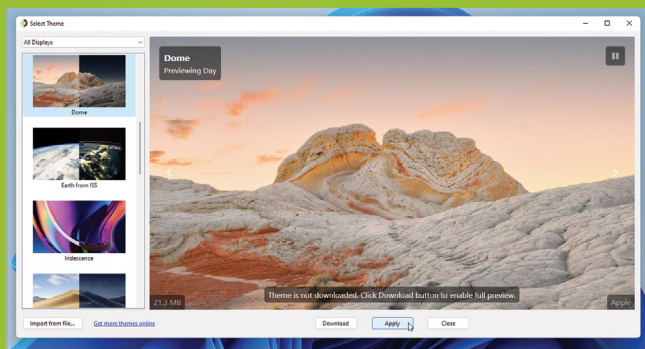
» Download the program and run through the installer—for the most part, the defaults should be fine, but pay attention to the "Launch Rainmeter on startup" option if you're not sure you'll want to use Rainmeter all the time.

» Once installation is complete, leave "Run Rainmeter" checked and click "Finish". Rainmeter ships with a single skin—Illustro—and enables four of its seven available widgets by default. In the center of the screen, you'll see a Welcome panel with some information and links to further information, while three further widgets—Clock, System, and Disks—appear in the desktop's top-right corner [Image A].

4 MANAGE SKINS

These widgets are all floating, so can be moved by dragging and dropping. They are made up of two basic elements: Measures, which gather information from various sources, and meters, which determine

GET A DYNAMIC DESKTOP



Are you jealous of macOS's dynamic desktop? It works by updating the background wallpaper periodically depending on the time, offering different variations on the same image to reflect sunrise, daytime, sunset, and finally night.

You can emulate this feature on your Windows desktop with the free and open-source WinDynamicDesktop (<https://github.com/t1m0thyj/WinDynamicDesktop>). Download the portable app to have a play, then use the installer to make it a permanent part of your system if you like what you see.

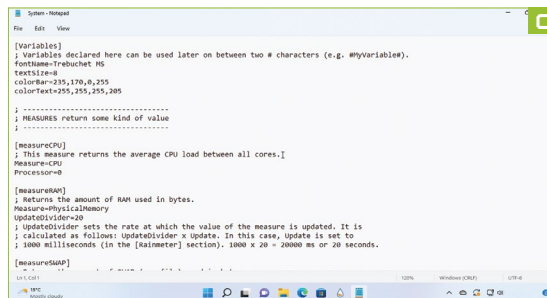
Click "Download" then "Apply" to switch your wallpaper to one of those included with the program, or click "Get more themes online" to access over 200 themes online, most of which are free (others typically cost \$1.49 each). Once downloaded, extract the .ddw file and click "Import from file" in WinDynamicDesktop to add it.

what the widget displays and its basic structure (including frames, backgrounds, images, charts, buttons, and so on).

» Each widget provides a mixture of information and links to other elements—for example, not only does System display your current CPU, RAM, and SWAP usage, but if you click its heading, it opens Task Manager. Similarly, Disks displays the C and D drives, and clicking either opens the relevant drive in File Explorer.

» Widgets can be moved around the screen simply by dragging and dropping, or you can right-click them to bring up a pop-up menu offering additional options. Choose “Manage skin” to bring up the “Manage Rainmeter” dialog [Image B], which is also accessible via Rainmeter’s Taskbar notification area icon. Here you’ll see you can precisely position the widget using exact coordinates, choose a different display to show it on, set its transparency level, and even use the “Position” drop-down menu to “layer” it in relation to other widgets and desktop elements.

» The dialog lists all available widgets for the current skin, including those not yet visible. In the case of Illustro, there are additional widgets to display the state of your Recycle Bin, provide network stats, and offer a quick and easy way to search Google without leaving your desktop. Simply expand the relevant folder, select the .ini file, and click “Load” to show the widget; click “Unload” to remove any unwanted ones from the screen (or just right-click the widget and choose “Unload skin”).

 EDIT WIDGETS

You'll notice an "Edit skin" option appears both on the pop-up menu and within the "Manage Rainmeter" dialog for each widget. Selecting this opens the widget's underlying .ini file in your text editor—if nothing happens after clicking "Edit," switch to the "Settings" tab, and verify the path to the Editor listed—change this to `C:\Windows\System32\notepad.exe` or click "..." to select your own text editor if necessary.

» You'll see the text file contains pretty much everything you need to know about the widget in question, and follows a logical format:

[Section]

Key=Value

» Choose one of the default widgets and you'll see plenty of descriptive information to help you understand what keys do what [Image C], although much of it is self-explanatory—for example, X and Y refer to coordinates, while W and H determine an element's size, and Text is what you see on screen.

» After making changes, choose “File → Save,” then switch back to the “Manage Rainmeter” dialog and click “Refresh.” How much information is defined in the .ini file determines how configurable a widget is—some authors provide more options than others. You may find some widgets, such as Disk, come with more than one .ini file—this enables you to configure variations (in the case of Disk, the widget either shows the capacity of a single drive or two drives), but note that only one .ini file can be loaded for any individual widget at any one time.

» For more on skins, visit <https://docs.rainmeter.net/manual/skins/> to work your way through Rainmeter's extensive documentation and reference guide.

 GET MORE SKINS

There's no need to design your own skins and widgets from scratch—there are literally hundreds of skins out there, sporting an almost infinite array of designs. These are organized into repositories, of which there are five major ones for Rainmeter—you'll find links to them all at www.rainmeter.net/discover/ but the biggest one by far is DeviantArt's—click the "Skins" link under "Gallery Folders" to browse by category. When reviewing results, scroll down to look for a link to the suite or skin's own page, often hosted at GitHub.

» You'll notice many of these skins have their own unique look and feel. For example, the Monterey Rainmeter suite (see <https://github.com/creewick/MontereyRainmeter>) has a series of widgets in the style of macOS **[Image D]**.

- » Skins are packaged as .rmskin files—simply download these to your hard drive, double-click the file, and follow the prompts to install the skin and any widgets

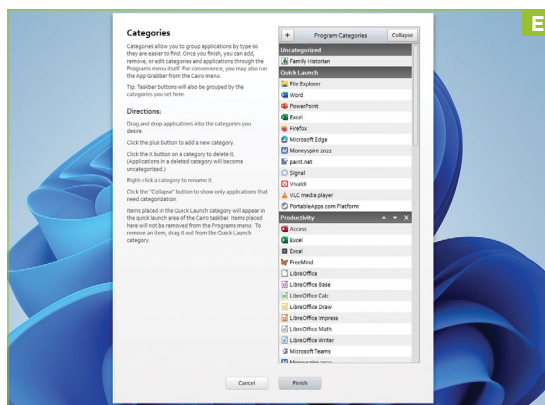
» Once installed, all available skins are accessible under the “Skins” tab under “Manage Rainmeter.” You can load widgets from multiple skins at once, although their different styles may clash—if this is the case, see whether the new skin offers the equivalent widgets to replace those from another skin.

 **TRANSFORM YOUR WINDOWS DESKTOP**

» Once downloaded, just run through the installer—note, if you run Cairo in place of Windows Explorer (rather than overlay it), you lose access to UWP/Windows Store apps and features, which is why this option is disabled by default. Once finished, leave “Start Cairo Desktop Environment” checked and click “Finish”. The Windows Taskbar slides out of sight, then Cairo’s desktop pop-ups, and you’re taken through a welcome wizard.

 GET ORGANIZED

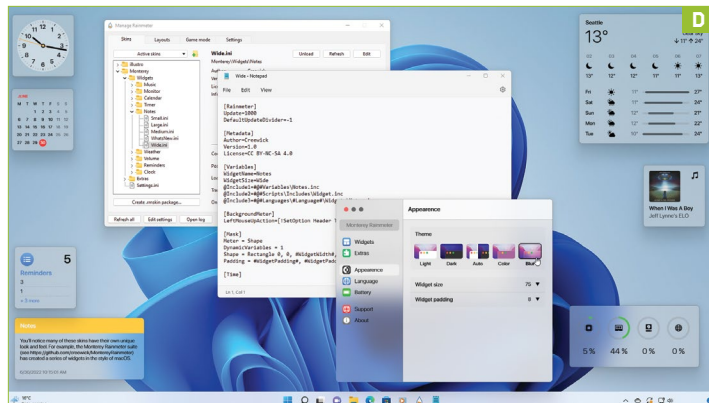
100



» You now find yourself at the desktop proper. Use the annotation on page 59 to familiarize yourself with its layout, then click the folder button on the navigation toolbar to select which folder you'd like to view on the new dynamic desktop. Its contents fill the screen—if there are too many folders and files to fit, use the scrollbars at the bottom to move around the folder, or click the Cairo menu button and choose “Cairo Settings → Desktop tab” to switch to small icons. While there, you can toggle the dynamic desktop feature on and off, plus set a new home folder for Cairo to default to.

KEEP TWEAKING

» Should you wish to rearrange your programs and categories, open the Cairo menu and choose “App Grabber” to bring up the wizard you used earlier. The Cairo menu also provides you with power options, shortcuts to the Run command and Task Manager, plus—if you want to return to your regular desktop—the magic “Exit Cairo...” command. ☺



RAINMETER TIPS & TRICKS

If you find Rainmeter's monitoring tools interfere with your full-screen gaming, you can manually disable them when running D3D full-screen games via the "Game mode" menu on

restore the current layout or load a specific one.

Finally, to offload some of Rainmeter's processing, drawing, and memory demands to the GPU, check "Use hardware acceleration" under "Settings." You can also configure logging here if troubleshooting.

For more tips, see Rainmeter's dedicated Tips & Tricks documentation (<https://docs.rainmeter.net/tips>).

Machine of the Month: Commodore PET (1977)

YOU'LL NEED THIS

VICE

<https://vice-emu.sourceforge.io>

You do not need any Commodore system ROMs—the emulator comes pre-loaded with a BIOS.

THIS MONTH, WE COVER a historic pillar of personal computing. Alongside the Apple II and Tandy TRS-80, the Commodore PET is one of three major computers (aka The Holy Trinity) that are credited with starting the home computing revolution, and its architecture would later underpin Commodore's most popular machines.

As you might expect, the PET is full of quirks and can present some technical headaches to a modern user, so after taking you on a brief history tour that goes all the way back to the mid-1970s, allow us to guide you through emulating the Commodore PET. —JOHN KNIGHT

1 DEVELOPMENT AND LAUNCH

The PET's story begins in 1976. In an attempt to match rival Texas Instruments, which was making its own processors, Commodore acquired chip manufacturer MOS Technology—maker of the now famous 6502 CPU. Commodore had a presence in the calculator market and wished to continue in this direction, but 6502 chief designer Chuck Peddle would change all that.

» At that time, the MOS 6502 had barely been used, and home computing was still a new concept. Frustrated by not seeing his processor used to its potential, Peddle convinced Commodore boss Jack Tramiel to focus on computers, which he perceived as the future of technology, instead of calculators.

» The PET was first announced in January 1977, when it was demonstrated at Chicago's Consumer Electronics Show. First orders were taken in June, although deliveries didn't begin until December, giving the Apple II and Tandy TRS-80 a headstart.

» The original PET model, the 2001, was a large all-in-one design with the keyboard, monitor, and tape drive all built into the same chunky 44lb steel chassis. Powering the machine was a standard 1MHz 6502 processor, with 4KB of static RAM.

» For an operating system, the PET was the first mass-market machine to run Microsoft BASIC (branded as Commodore BASIC), which could do floating-point computations, out-classing Apple Integer BASIC.

» Cassette was the only storage method available on launch; the tape drive was an off-the-shelf product with slight modifications, mounted inside the chassis. The original keyboard, meanwhile, was criticized for being far too small.

» The PET has no graphics—everything is 40 columns text-based and restricted to the machine's PETSCII character set, which can't be modified. This is all viewed through a nine-inch black-and-white screen. It originally came with no sound, although owners eventually worked out a wiring hack via the user port to generate simple noises.

» Initially, the PET was sold for \$495 via mail order with a waiting period, but after overwhelming demand, Tramiel increased the price to \$595. Commodore then promoted a \$795 8KB variant, promising it would ship sooner than 4KB models.

2 SOFTWARE

The PET's software range was largely business and science-oriented, with popular office software like the WordPro series, and advertisements for adrenaline-pumping applications such as Mortgage Analysis and Basic Statistics Package. Nevertheless, coders still found ways to have fun. The PET's character set is extensive and was put to great use by many

games. Like the Sinclair ZX81, clever coders worked out exploits to grab slices of PETSCII characters one line at a time to create images close to bitmap graphics.

» To pick some gaming highlights, *Millipede* (1982), *Space Invaders* (1980), and *Lode Runner* (1983) all provide classic gaming that makes good use of PETSCII characters. For something that pushes the machine harder, *Voyager 1* (1982) has the mechanics of a first-person dungeon-crawler, but with a futuristic spaceship setting. *Shootout* (1982) is a sophisticated 3D space shooter with impressive movement that looks like real graphics. For modern gaming options, check out *Pet Tetris* (2010) and *PETSCII Portal* (2021), but chief praise must be given to YouTuber David Murray (aka The 8-Bit Guy), who has developed the cult arcade/strategy/puzzle game, *Attack of the PETSCII Robots* (2021).

3 LEGACY

The PET was an immediate hit and quickly established Commodore's new direction. The line was soon upgraded, starting with the keyboard—Commodore switched to the now-familiar external tape drive design to make room for a bigger keyboard.

» The screen was enlarged to 12-inch, using a green-on-black display, plus a small speaker was added, so owners no longer had to hack wires into the user port.

» Later models would receive RAM upgrades, with either 16KB or 32KB maximum. Technological advances eventually allowed up to 96KB, plus machines with 80-column text modes, though software was not usually compatible between 40 and 80-column machines.



» *Fire!* (1980) is a good visual demonstration of the aesthetics provided by Commodore's character graphics.

» Jack Tramiel chose the name PET to positively associate it with the Pet Rock craze, back-naming it the Personal Electronic Transactor.



» Floppy drives were eventually released in 1979, including both 5.25-inch and 8-inch models, as well as external hard drives several years later, with 5MB and 7.5MB variants.

» The PET series eventually morphed into the CBM line, designed for the business market in Europe. Sales of the PET began to decline in 1982, with around 219,000 sales worldwide—a solid figure for the time—when it was superseded by the VIC-20.

4 EMULATION

The most popular emulator for the PET is VICE, which supports Windows, Linux, Mac, and many other platforms.

» For Windows, head to <https://vice-emu.sourceforge.io> and download the latest build. After extracting the package, go into the new folder, open the bin folder, and manually open xpet.exe. You might want to make a desktop shortcut.

» For Linux users, VICE is available in distribution repositories, but we don't recommend this as it will probably be missing core system files due to licensing restrictions. You can get these files from a source tarball, but it's much easier to install the Flatpak package instead, available at Flathub or possibly in your distro's app store. Flatpak should install entries in your system menu.

5 LOADING SOFTWARE

Most software online is .d64 disk files or .prg program files. Regardless of format, VICE makes life simple by handling these files through its "Smart Attach" function, which auto-detects file types, automatically enters LOAD commands, and even activates Warp Mode while your program is loading.

» To get started, go to "File → Smart attach." Choose your image from the file browser, then click "Autostart." VICE tries to load your files by entering standard LOAD commands. If you get stuck at the BASIC prompt with nothing happening, just enter:

RUN

» However, this simply loads whatever program the PET finds first. Sometimes you need to specify the name of a program, such as when loading files from a compilation disk. Newer versions

FINDING SOFTWARE

PET software is strewn randomly across the internet, rather than in one go-to website. As usual, Archive.org has software, but it's also worth checking out the repository at <http://8bitfiles.net/cbm/pet> and <http://petlibrary.tripod.com> among other sources. We can't advocate downloading copyrighted material, but there is plenty of public domain software that is legally fine.

of VICE can be of assistance here, as when you select a disk image during the "Smart Attach" process, it lists any files within the image in the Image Contents panel on the right—even if they're still zipped.

» Any usable programs have a number on the left, the program name in double-quotes in the center, and a PRG designation on the right. For instance, the game *Joust* on PET Games Disk 11 was listed as: 21 "JOUST" PRG

» On newer versions of VICE, you can simply select this line from the Image Contents panel, then click "Autostart" to load the game. With older versions, you need to take a harder route, entering manual commands. Start by writing down the program name shown in the Image Contents panel. Instead of clicking "Autostart," click "Attach," then manually enter the LOAD command. Sticking with *Joust*, the command looked like this, however, you should place the name of your program between these double-quotes:

LOAD "JOUST",8

» Followed by:

RUN

6 TROUBLESHOOTING

Unfortunately, machines from the PET range aren't entirely compatible with each other and you often need to engage in some trial and error.

» Start by clicking "Preferences → Settings." In the Settings window, click "Machine" and choose "Model" from the drop-down menu. Most problems center around "Model" and "Display Width".

» If your program has characters spread around in strange positions, the program is probably running in either 40 or 80-column mode incorrectly, and needs to be switched from one mode to the other in the "Display Width" section. If your program crashes randomly or fails to boot at all, it probably requires another PET model. Try starting with something from a much earlier or much later series. ☹

SPECIFICATIONS

COMMODORE PET (1977)

CPU:	MOS Technology 6502 @ 1MHz
RAM:	4-32KB; 96KB
Launch price:	\$595
Graphics:	Monochrome text, 40 × 25 or 80 × 25 columns
Storage:	Cassette, 5.25-inch floppy, 8-inch floppy, and external hard drive
OS:	Commodore BASIC 1.0

Released:	June/December 1977
Production:	1977-1982
Worldwide sales:	5.7 million



» YouTuber David Murray has also released PET Draw (2015), which enables you to draw an image by automatically assigning the closest characters to render it.

Word Art Logos with GIMP

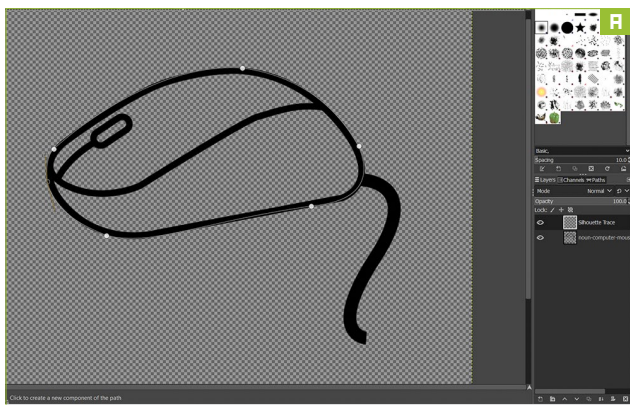
YOU'LL NEED THIS

GIMP 2.1

OS: Windows 7 or newer

USING WORDS TO CREATE AN IMAGE can be a visually striking way of displaying a brand name and also illustrating what the brand represents—two for the price of one, if you like. We can achieve this effect by bringing in a silhouette, usually a side profile, and adding text inside this to create a logo. In this tutorial, we will be doing just that and showing you how to spice up a plain text design into something artistically exciting.

Before we start, we need to have a brand name in mind, an item that relates to the brand, and a silhouette of said item. The letters from your brand will essentially form the silhouette, therefore, creating an image from a word. To get your silhouette, you can use a number of media sites. We chose ours from the Noun Project, which focuses on silhouettes and icons. You could use your own image and trace around it using the path tool. If not, Unsplash is a handy resource for finding royalty-free images for you to practice these tutorials with. —SAM LEWIS



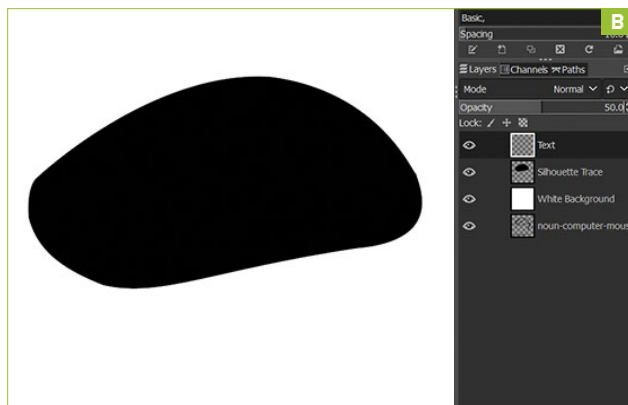
OUTLINE PLANS

After you have decided on your silhouette and name, bring your silhouette file into GIMP. You can either drag and drop it into your workspace or go to File, then Open and find your image. Our image is called 'Computer Mouse' by Laurenda Gauthier from NounProject.com. Once that file is loaded into GIMP, head to the bottom right corner of the application and click on the icon containing a page with a plus sign. This will add a new layer to your image. We named this layer 'Silhouette Trace', also, make sure the fill type on this layer is transparent. **[Image A]**

» Next, use the path tool to outline your silhouette on the 'trace layer'. Click dots around this and make your way around the shape. To adjust the curvature of your line, click on the points and drag out the lines until you're happy with them. When you get to the last point, hold the 'CTRL' key and click on the first point to close the path.

PATH LESS TRAVELED

Now that the path has been completed, hit the 'ENTER' key to make this into a selection. Then head to the top, go to edit, and in the drop-down list, select 'Fill with FG color'. Make sure your foreground color is black before doing this and it will now create a silhouette for us to work with. To help us when creating our text, we need to add another layer, this time changing the fill to white and dragging this layer below our 'traced silhouette' layer. [Image B]. Then, add one more transparent layer on top and name this text, and we will change



the transparency of this down to around 50 percent at the same time. The transparency slider sits above the layers panel on the right-hand side of the application.

ROUGH AND READY

3 We can now begin by roughly writing out our text into the silhouette. Using the brush tool, sketch the brand name to fill out the edges of the shape. This doesn't have to be precise [Image C], it's just to get an idea of how your design will look. As you can see, ours is





far from perfect, but make sure you leave gaps in between each letter as we will be using this space to help with our logo.

» After you've filled the shape with your brand name, click back onto the 'trace silhouette' layer and use the eraser tool to draw lines around your rough guide [Image D]. This will take away from the silhouette, again you can do this roughly, then zoom in and touch up the areas using our example as a guide.

4 CUTTING CORNERS

To create the shape using the letters, we need to use the eraser tool to cut away any empty space within the text. As you are cutting away, keep your original letter layer on as a reference so that your lettering is still visible. This process takes time, so no need to rush.

» Erase the lettering in stages, but if you keep holding down the mouse for a while and make one mistake, a simple CTRL + Z will undo much more work than is necessary [Image E]. Take it from us, that usually results in a large sigh and instant regret. We aren't aiming for a super smooth finish here, the art style is rudimentary and sketch-like, so it doesn't need to be properly polished. Just make sure that the letters look like they are from the same font style.

5 NEGATIVE SPACE

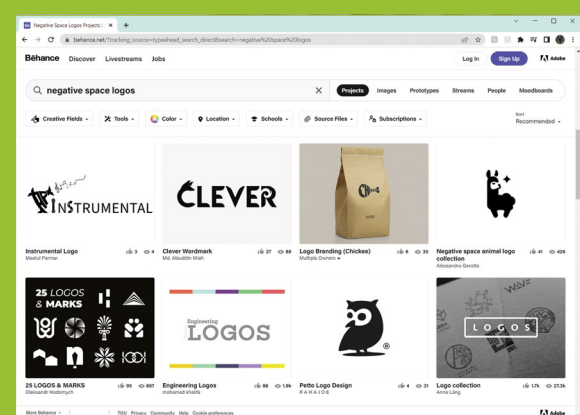
So the erased area has now become negative space which is what will form our text. It still follows the original silhouette of the mouse in the first place, which gives us our 'image from text' look. To finish it off, we can add in the cabling for the mouse with a simple brush stroke to add more emphasis to the peripheral.



» What you end up with is a hand-drawn artistic logo that delivers both the name and also a visual link between the company and what it does. Using negative space is a great way to create your own typography in design work. It's unique and carries human qualities that can't be produced artificially.

» You can apply this technique across many different styles of logos. It can also be taken further by altering the silhouette and background colors or by adding a border or even a 3D effect to the lettering in your design, for example. [Image F].

NEGATIVE SPACE



In art and design, the space that falls around and in between the subject is known as the negative space. The remainder of the image, which is typically your focal point, is known as positive space. Rubin's vase is one of the most popular examples of this working in action. The positive space, the vase in the middle, is the main focal point. However, the negative space on each side of the vase creates the illusion of two faces staring at each other.

Using negative space to your advantage is a great way to add depth to your designs and create something clever with an eye-catching element of illusion to it—this may get the audience to do a double-take. If you want to check out some cool examples of negative space, Behance is a handy platform where designers can check out other users' work, get inspiration, and show off their own pieces.

BUILD IT

SAM LEWIS, STAFF WRITER



Teenage Engineering Rig

Is this the PC setup Meccano lovers have been seeking?

LENGTH OF TIME: 2-3 HOURS

LEVEL OF DIFFICULTY: MEDIUM

THE CONCEPT

LOOKS AREN'T EVERYTHING, but they do play a big part in this build. We can't really start without first mentioning how cool this mini DIY PC setup is. A huge part of building computers is the customization scene and this Teenage Engineering computer-1 fits right into that. It's full of quirkiness and comes flat-packed, which certainly gets rid of those bulky case boxes that sit around your house for years on end.

Of course, size limitations within this case also result in power limitations—that's just the way the cookie crumbles—but we aren't going to let that weigh us down. Chances are, if you're building a machine like this, you're not after a lightning-fast liquid-cooled gaming monster sent down from the PC gods. A rig like this is more about the charm, character, and design.

The computer-1 case only supports a Mini ITX motherboard, SFX power supply, and a dual-slot GPU measuring up to 180mm by 130mm. We aren't expecting nitro speeds here as we won't be including a GPU. Although this isn't strictly a budget build, we don't want to exceed the \$1,000 mark by too much, so let's see what we can achieve for that price tag in this beautiful case.

Our aim here is to make a 12th-generation system inside that is more than good enough for day-to-day work and occasional light gaming. So read on to find how to assemble this sheet metal PC and see how it performs in our benchmarking tests.



THE INGREDIENTS

AT A REASONABLE PRICE, we chose ASRock's B660M-ITX/ac LGA1700 mobo. Choosing a Mini ITX board can be tough thanks to limited compatibility. However, with a digital PWM design making this board's CPU Vcore voltage more stable, it should run more efficiently than analog alternatives. It supports PCI Express 4.0 M.2 SSDs, so will work well with our 1TB Samsung 980 Pro.

It may be a substantial SSD but, as performance is limited, it should help with file transfers and loading times. We won't be filling this with games, so 1TB is a healthy capacity for this mini workhorse. We also have 32GB of PNY XLR8 Gaming REV RGB memory. These snappy RAM sticks run at 3200MHz and are a good match for our dual DIMM slot motherboard, although you can barely see the lighting though through the gaps in the panels.

We went ahead with the Intel Core i5-12600K with Alder Lake's hybrid architecture, which divides ten cores (six performance, four efficient) for foreground and background tasks. As we aren't using a dedicated GPU, we're relying on this chip's integrated Intel UHD Graphics 770 to provide smooth performance.

As this PC won't be under too much load, we will use Intel's 12th Gen stock cooler, the Laminar R1. It's a suitable cooling solution for this build and looks better than the last variant. Paired with it, we have an 80mm BeQuiet! BL037 Pure Wings 2 PWM case fan. The side panel only supports 80mm fans and should result in a quiet running system. The case only supports SFX power supplies, so we chose a solid 750W 80+ Platinum PSU from Corsair to fill this space. With all these components working in unison, this rig should be more than just a pretty case.

INGREDIENTS

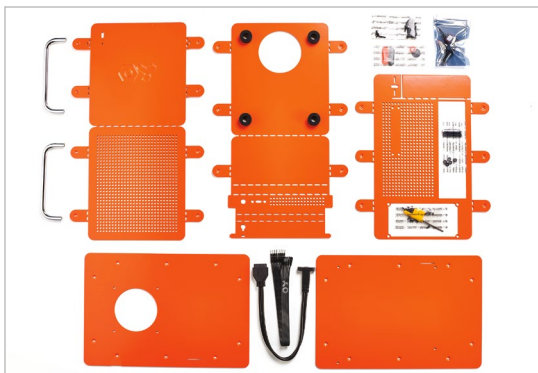
PART		STREET PRICE
Case	Teenage Engineering computer-1	\$195
Motherboard	ASRock B660M-ITX/ac	\$119
CPU	Intel Core i5-12600K	\$250
CPU Cooler	Intel Laminar R1 Cooler	\$N/A
Case Fan	BeQuiet! BL037 80mm Pure Wings 2 PWM	\$10
Memory	32GB (2x 16GB) PNY XLR8 Gaming REV RGB DDR4-3200	\$119
SSD	1TB Samsung 980 Pro w/ Heatsink PCIe 4.0 NVMe SSD	\$175
PSU	Corsair SF750 80+ Platinum PSU	\$160
OS	Windows 11 Home 64-bit OEM	\$32
Total		\$1,060

1

FLAT AS A PANCAKE

WE MAY HAVE gone over the top with laying out the Teenage Engineering computer-1 in the way we have. However, whenever starting with a DIY kit, it's best to take everything out and make sure you have all the parts, fittings, and tools necessary to start building. The last thing you want is to get close to the finish line and realize you're missing that one all-important screw that holds a crucial element of the case together.

Speaking of which, the screws used in this build are tiny star-headed types so you don't want to lose one of these. There is a fancy star-headed screwdriver thrown in too, thanks to Teenage Engineering. Other than that, the kit consists of five panels, feet, handles, front panel connectors, and all the cables you'll need.



2

PREPPING THE KIT

BEFORE WE LAUNCH into this build, there are a few important steps we need to take to save ourselves some time later down the road. First, we need to tap all the screw holes on the sheet metal. To do this, take the screws and the screwdriver tool provided and push them through every hole turning the screw left and right until it taps in. Make sure not to overdo it as you need the screw holes to be tight when securing the build together.

Next, we have to bend all the folds and tabs on the build. A great motto from teenage engineering is "think twice, bend once". If you bend a tab incorrectly and have to bend it the other way, this can greatly weaken the joint. Use a 90° angle to bend the folds and tabs accurately. As a heads-up, where the front panel is, it can get tight, so spend the most time perfecting these folds on the metal. We can add our grab handles to the top of the case at this stage too. These attach one screw hole in from the sides and use the case's screws. The feet can also be added, these simply push into the holes on the bottom of the case.



3

POWERHOUSE OF THE BUILD

THE NEW RECTANGULAR LGA 1700 socket makes it easier than ever to install a CPU onto our ASRock motherboard. Unfortunately, the pins are still just as delicate, so remember not to touch them and always grab the CPU delicately by the sides. Release the retention bar from the hook and lift the arm to open the socket, then align the CPU so that the arrow on the processor matches that of the motherboard. Gently rest the CPU down into the socket and then repeat the initial steps in reverse order to secure the processor in place.



4

A BREATH OF FRESH AIR

ALTHOUGH YOU WON'T be able to see it in this particular machine, the Intel Laminar R1 is a much-welcome new design compared with the cheaper-looking Intel stock coolers of the previous generation. One facet shared by both generations is an easy install—there are no back brackets needed here. First, add a pea-sized amount of thermal paste to the center of the CPU, then rest the cooler block onto the processor, making sure the feet of the cooler fall into the screw holes on the motherboard.

We rested our mobo on the foam from the box so that we could push the pins through from the Intel cooler. When clipping it into the board, work diagonally so even pressure is applied. A firm click will assure you that your cooler is connected properly. Also, consider where your CPU fan cable will go and make sure it reaches the header on the motherboard.

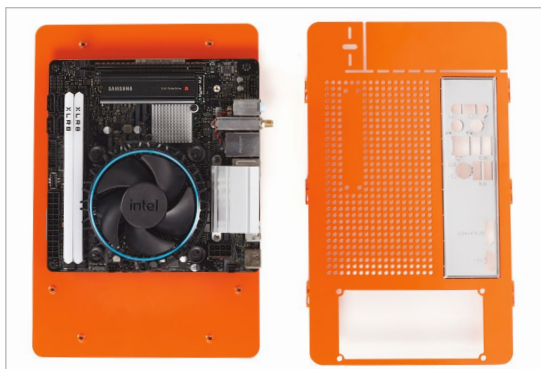


7

PC + METAL

AT SOME POINT we have to connect our motherboard to our case, and that time is now. This was one of the easiest motherboard installs we've done, mainly because the case is still in bits. Take the left side of the case and face the outside of the panel downwards with four screws through the back. Then tighten the four standoffs onto these screws and rest the motherboard on top.

Four more screws secure the motherboard down, again using the supplied tool. When tightening the board to the case, work diagonally. On the back panel of the case, the motherboard's I/O shield clips right into place. Just make sure it lines up with the ports on your motherboard—because the first time around, we didn't.

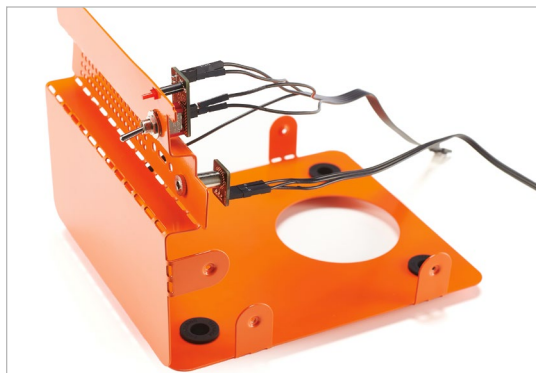


8

FRONT PANEL

FROM ONE EASY STEP to a not-so-easy step. This is where the build starts to get fiddly, though it was bound to happen at some point. In this section, we need to add the front switch and auxiliary jack. These two connectors come with a washer and a nut pre-attached so we need to take these off, then feed the switch and auxiliary jack through the front panel and, finally, tighten these on using the nut and washer.

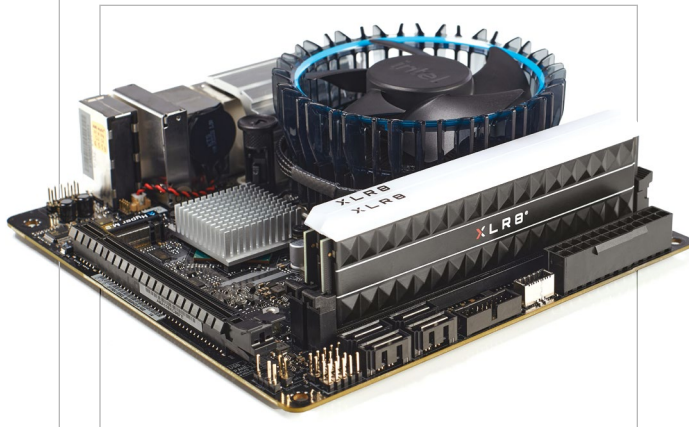
Fitting the pin header cables is where it gets trickier, so be sure to match the cables up with the labeling on the back of the switches. These cables aren't the most secure so be careful when maneuvering other components around as you might pull them out.



5

RANDOM-ACCESS MEMORY

WE ALMOST ENCOUNTERED an issue early on with this Meccano-style build. An issue that actually has nothing to do with the case. This was the clearance around our Intel Laminar R1 cooler, or rather, the lack of clearance. We had a tight squeeze getting our first stick of RAM into position, which left us debating whether to strip the RAM down to its bare bones. Luckily, we didn't need to, so we got the PNY RAM installed. To do so, loosen the clips at the top of the DIMM slots and make sure to align the notch in the slot with the notch on the RAM. Once aligned push it down and the clip will lock it in place.

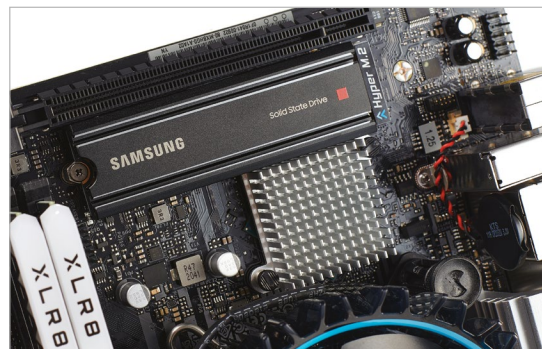


6

FANCY THUMB DRIVE

AS OUR MOTHERBOARD didn't come with an SSD heatsink, we had to choose an SSD with one pre-installed. Due to our motherboard's M.2 slot being on the left-hand side when you look at it straight on, our Samsung drive looks as though it is upside down. Again, as all of the looks are focused on the outside of this case and you can't peek inside, this isn't too much of an issue, but it's still playing on our minds a little nonetheless.

To install this M.2 drive, keep it upright and angle the connector into the port at a 30° angle, push it in and then push it down flat. The screw hole on the drive should align with the hole on the motherboard. Then using the tiny M.2 screw from the motherboard's box, tighten this down to the board.



9

A LITTLE FAN

TO FINISH the cooling elements of this rig, we need to add in our BeQuiet! 80mm fan. We want to bring the cool air inside the case and over the motherboard towards the CPU fan. Remember, faces suck, so place the fan with the face pointing outwards and, using four screws from the case, tighten this onto the panel with the fan cutout. Whenever installing a component, consider the cable placement and whether it will reach the motherboard. Cable management isn't too much of an issue in this build but it's always handy to keep things organized and clean.



10

A LITTLE PSU

ALTHOUGH THE PSU needs to be small in size, our choice still packs a punch. Before we attach all the panels together we must secure this onto the back panel underneath the I/O shield. The fan on the PSU must be facing downwards as this will sit on a panel with the circular cutout on the bottom. Tighten this using standard screws for a PSU. We had to slightly force these screws through the case as it was a tight fit. To avoid messing around in tight spaces later on in the build, we also added the motherboard and CPU cables into the back of the PSU at this stage.



THE CONCLUSION

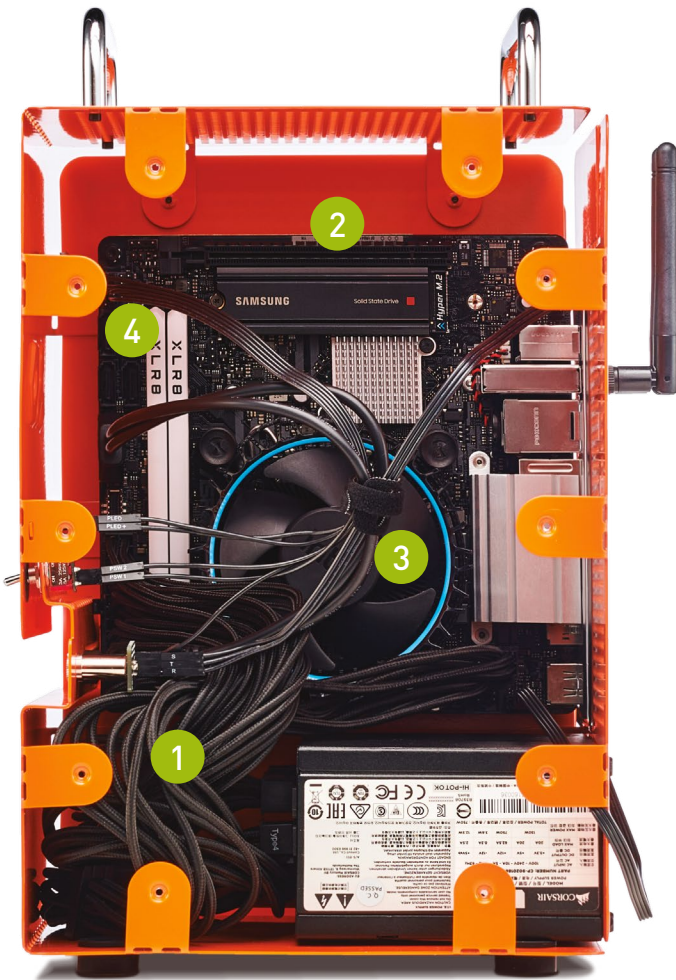
RIGHT FOLKS, this has been one of the most fun builds we’ve done in a while. It brought us right back to our childhoods, getting hands-on and physically making the case meant we were much more involved with this machine. All in all, the build went a lot smoother than we had initially predicted. A Mini-ITX system can often throw up some slight issues due to the fiddly nature of the form factor, and that’s in a traditional case. Sure, there were a few annoyances along the way, including bending the front panel, almost missing out on the USB-C connector, and a cramped area within which to work, but a build wouldn’t be a build without a few minor setbacks.

Forming a case around a system was a style of building that was new to us and, as we mentioned, it gave us a closer bond with the PC. While it might have been cool to be able to paint the panels ourselves, we love the orange look the Teenage Engineering case is rocking here. This mini machine is a great addition to any desk, a sort of futuristic design mixed with a retro color scheme.

But, although we are big fans of this PC’s looks, unfortunately, the performance doesn’t quite live up to its eye-catching exterior. Although it has a great presence, our benchmarking shows that the gaming performance is pretty retro too. Of course, these are tested at 1080p running on Ultra settings with no GPU, so we aren’t exactly surprised by the results. However, when we turned down the sliders and ran the same titles at lower settings, we only achieved frames of low to mid-30s. Not exactly ideal but again, we are running no GPU here, just the integrated Intel UHD Graphics 770.

Thankfully, the results in other areas were more impressive. When it came down to CPU performance we were seeing increases of around 20 percent on our Cinebench results over the system we were challenging it against, the 1080p build. What didn’t surprise us was how strongly the Samsung 980 Pro SSD performed in our CrystalDisk tests. It achieved read speeds of around 7000MB/s and write speeds of over 5000MB/s, just as advertised, which isn’t bad at all. So this resulted in the PC running smoothly for the majority of day-to-day tasks, especially paired with our PNY XLR8 RAM sticks. This machine is certainly capable of being a daily driver, running multiple programs at once, and makes for a quirky, fun, and original rig.

At the end of the day, if you’re after a Mini-ITX machine and also want to game on it, chances are you’ll opt for a more sensible case that has a larger GPU clearance. The computer-1 from Teenage Engineering falls much more down the hobbyist route than



- 1 Yep, we think we have too much cabling going on here. Shorter PSU cables next time maybe?
- 2 Our system has all the looks, but a GPU would certainly make this a more versatile rig.
- 3 Cable management wasn’t essential here, but we tried to keep the cables tight so they don’t hit the CPU fan with a cable tie.
- 4 Our PNY RAM sticks look great, it’s just a shame we can’t see them in all their glory underneath the computer-1.

a practical case. If you like getting hands-on and want a reliable daily PC setup, then you can create a machine inside of this case that can do so, just don’t expect to be live streaming *Elden Ring* from it any time soon.

Overall, we had a blast with this build, however, we have our fingers crossed that Teenage Engineering has a larger case in the pipeline so we can get some more oomph from an interesting case such as this. ⚡

BENCHMARKS COMPARISON

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,537	1,865 [21%]
Cinebench R23 Multi-Core (Index)	10,632	13,186 [24%]
CrystalDisk QD32 Sequential Read (MB/s)	3,287	7,072 [115%]
CrystalDisk QD32 Sequential Write (MB/s)	2,419	5,228 [116%]
3DMark Fire Strike (Index)	24,814	2,420 [-90%]
Cyberpunk 2077 (fps)	68	13 [-81%]
Metro Exodus (fps)	75	9 [-88%]
Total War: Three Kingdoms (fps)	72	12 [-83%]

Our 1080p zero-point consists of an AMD Ryzen 5 5600X, an XFX Speedster QICK308 Radeon RX 6600 XT, an Asus ROG Strix B550-F WiFi, 16GB of XPG Gammix D45 DDR4-3200, and a 1TB ADATA Legend 840. All games tested at 1080p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

LAB NOTES

SAM LEWIS, STAFF WRITER



Form factors

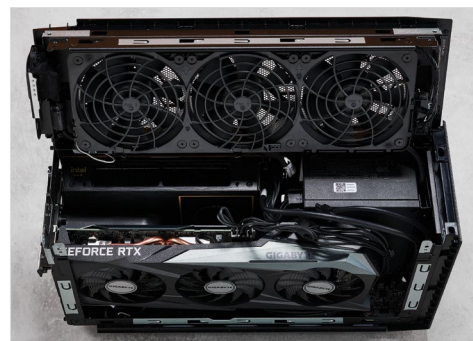
Does the size of the ship really matter?

I STARTED MY GAMING career on consoles, specifically the PlayStation. When I was younger, PC gaming wasn't really an option, as most of my friends either had a PlayStation or Xbox and it was a case of picking one or the other. It was more of a social divide than anything and choosing to game on a PC would mean that you missed out on a big part of my group's social life. At that age, of course, it was more about hanging out with friends than the pure gaming experience and party chats were a great way of being social.

There were other issues, such as ease of use. PCs can take up a lot of space and are more complicated than a console, which is pretty much ready to go out of the box. PC gaming wasn't the cheapest option either. Sure, we had laptops and a desktop PC at home, but these were mainly for homework and perhaps even the odd browser game.

Anyway, my point is that what I most enjoyed about console gaming was the form factor and ease of use, something I'm still trying to recreate in PC gaming to this day. When I became a writer at *Maximum PC*, it took me no time at all to realize the benefits of the PC over a console. However, if you want the latest and greatest in performance, size is inevitably going to be a compromise. Liquid-cooled machines are substantial, extremely pricey, and you'll probably need to reinforce your desk to support one.

At *Maximum PC*, we've tested and built many small form factor machines recently, from the Teenage Engineering computer-1, Geekom Mini-IT8, and the Intel NUC 12 Extreme 'Dragon Canyon'. The latter is something I'd personally consider as it can



Mini machines have always caught our eye.

fit a decent GPU inside, has a great cooling system, runs quietly, and is 'console sized'. For me, size matters and this little machine ticks a lot of boxes. It just depends on what you are after. That's the beauty of PC building—there's something for everyone.



GUY COCKER

Editor-in-Chief

Two gaming monitors landed in the *Maximum PC* labs this month—a 4K Acer (see review on page 78) costing \$1,000 and a 1440p HP (page 80) costing under half that. I was obviously more excited about unboxing the 4K Acer, mainly because my daily driver is a 1440p monitor which leaves the RTX 3090 in my desktop rarely breaking a sweat.

The 32-inch Acer is fantastic, and playing games in 4K feels like a true luxury. But it was interesting to then compare it to the cheaper HP. It's even bigger at 34-inches, it's ultrawide so is arguably more immersive, and it too supports both FreeSync and G-SYNC. All that's missing is lots of inputs, but for a \$540 difference, I think most of us

would be happy swapping cables every now and then.

As someone who tries to stay at the cutting edge, it was a reminder that it's not always worth spending loads to do so. With the cost of living spiraling, I'm reevaluating every purchase I make and, for the first time in a while, I wouldn't hesitate to go for the cheaper option here.

It makes me wonder just how well the next generation of top-end cards from Nvidia, due to land at the end of the year for likely around \$2,000, will do in a market where people can't afford those luxuries. I still enjoy life's little pleasures, but right now, I feel the HP X34 life is more for me than the Acer Predator life—and that's totally fine.

AOC Agon PD32M is yet another disappointing mini-LED monitor.



Editor's Pick: Asus ROG Flow X16

Finally, a mini-LED screen that looks fantastic



MINI-LED WAS meant to be the next big thing in display tech, but so far it's been deeply disappointing. One of the first big opportunities for mini-LED to impress was with the revised 'Neo' version of the Samsung G9 mega-monitor. But, as was widely reported at launch last fall, it absolutely sucked.

Since then, things haven't really improved much. I was exasperated to find recently that the new AOC Agon PD32M suffers from pretty much all the same issues. The PD32M is an up-to-the-minute monitor with the latest mini-LED backlight tech, complete with no fewer than 1,152 zones. Sadly, in practice, it's about as clunky as the Samsung Neo G9.

In normal Windows usage, you can see the zones turning on and off. You also get obvious ugliness when placing dark objects next to light objects on-screen, where the brightness can't be controlled precisely enough and the edge of a lighter object is incorrectly dimmed. It wouldn't be acceptable on a \$200 monitor and it's absolutely unforgivable on something costing over \$1,000.

Moreover, you could argue that even 1,152 dimming zones is pretty pathetic. After all, on a 4K panel such as the PD32M, that works out to roughly one dimming zone for every 7,200 pixels. Hardly precise. Put another way, the actual resolution of the mini-LED backlight is about 45 zones by 25. Imagine if that was the actual pixel resolution? Quite.

Then there's the problem of programming the algorithms to control the zones. That inevitably creates a layer of complexity and an opportunity for things to go wrong. With the huge

mismatch between the zone count and the actual resolution, the dimming is never going to match what the pixels are showing, so compromises and trade-offs are absolutely inherent. Worse still, even if you've decided exactly what trade-offs to make, actually making them happen is another matter. Aligning the timing on the backlight to perfectly match the response of the LCD panel itself is incredibly hard.

Well, it's actually impossible to do it perfectly, so right there, you've introduced a new inherent flaw to LCD monitor tech all while you're trying to solve another, namely poor contrast performance. All told, the mini-LED monitors I've seen so far have been clunky and broken. They have been awful for SDR content and less than totally stellar for the HDR stuff—and that's supposed to be the whole reason for their existence.

Anyway, the craptastic experience had me convinced that mini-LED was largely a waste of time. At least, it did until I saw the new Asus ROG Flow X16. You can read the full review on page 76 to find out what it's like overall as a laptop. But its mini-LED screen is an absolute revelation.

It suffers from none of the obvious flaws of desktop mini-LED monitors. You can't see the backlight doing dumb things on the Windows desktop. SDR content works great. You can even adjust the overall brightness in HDR mode, something most HDR desktop monitors will not allow.

What's more, the X16 only has 512 zones and yet it still looks fantastic. OK, that's on a much smaller 16-inch screen, so the zone density is actually much higher than on a 1,152-zone 32-inch panel such as the AOC monitor. But in resolution terms, it's still pretty low. And yet it works fabulously. I'm sold. —JL
\$1,799, www.rog.asus.com

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PowerColor RX 6400 ITX

Bottom of the budget barrel

WHEN AMD ANNOUNCED the RX 6500 XT and RX 6400, it said the latter would be exclusive to pre-built OEM PCs. Several months later, AMD changed its mind and the Radeon RX 6400 is now available as an add-in board from several graphics card vendors. The PowerColor RX 6400 ITX perhaps isn't the ideal model, since the biggest selling points for the RX 6400 are that it doesn't require any extra power connectors and it can fit in a single-slot, half-height form factor. If you happen to have a slim PC, about the only other options besides the RX 6400 are extremely weak solutions such as the old GT 1030 or RX 550 from five years ago.

The Navi 24 at least brings some features up to the modern era. You get PCIe 4.0 support, ray-tracing hardware, and 4GB of GDDR6 backed by a 16MB Infinity Cache. However, the PCIe link is only four lanes, and in testing with a PCIe 3.0 connection, performance dropped by nine percent on average. The ray-tracing support also barely counts, and while we tested performance at 1080p medium, the best result from a demanding DXR (DirectX Raytracing) game was only 15fps, with several DXR games landing in single-digit frame rates. Finally, Navi 24 was originally intended for laptops where it would be paired with processors that

have integrated graphics and hardware for video encoding and decoding. To save die space, Navi 24 lacks any form of H.264 or H.265 encoding support—though it can decode those formats just fine.

Overall, graphics performance basically ties with the GTX 1650 GDDR5 solution that launched three years ago. The GTX 1650 was technically faster at 1080p ultra, although it was largely a pyrrhic victory because most games failed to reach 30fps. Adding insult to injury, the suggested price is \$10 higher than Nvidia's card—although it's getting difficult to find new GTX 1650 cards in stock, and they routinely sell for \$200 or more. GTX 1650 also has full H.264/H.265 encoding support, and there were actually a few models that ran with reduced clocks so that they didn't need a six-pin power connector.

Incidentally, AMD has fully locked down clock speeds on the RX 6400. Open AMD's Radeon Settings utility and you can't change any of the settings, not even fan speed. The same goes for MSI Afterburner. Which is fine, because this is clearly a budget-focused card and overclocking likely isn't at the top of anyone's list of features. With a 53W TBP (typical board power), even the tiny fans and heatsinks on half-height models

should cool the GPU sufficiently to let it reach its performance potential.

Sadly, it appears Nvidia saw AMD's budget sector plans and decided that it couldn't let the RX 6400 go unchallenged, so it just launched a 'new' GTX 1630 card. While the 1630 does have better video encoding hardware, that's about the only advantage. The GTX 1630 has just 512 shader cores and makes the RX 6400 look much better by comparison. It's also priced as high as the far more capable GTX 1650 that uses the same TU117 GPU, just with 50 percent more shader cores and twice the memory bandwidth. Both new GPUs end up feeling like they were moved into production back when cryptocurrency mining and severe graphics card shortages were ongoing, which is thankfully no longer the case.

This is a GPU for a specific niche—mostly users who want a slim graphics card. If you fall into that category, as slow and defeated as the RX 6400 is, it may be your best option. Some would even argue that for the intended market, the card performs admirably and warrants a higher score. Those who don't need a slim card and have PCs with six-pin or eight-pin power connectors have better options, such as the GTX 1650 Super or the previous generation RX 5500 XT. Both can be found on eBay for under \$150, and even used cards should still run fine as these models were not good for Ethereum mining. —JARRED WALTON



VERDICT

PowerColor RX 6400 ITX

■ **NICHE** No extra power required; half-height models available; as fast as the GTX 1650.

■ **POINTLESS** Slower than most GPUs; costs nearly as much as RX 6500 XT; no encoding hardware; x4 PCIe.

\$159, www.powercolor.com

BENCHMARKS

	RX 6400	RX 6500 XT	GTX 1650
Eight-Game Average	56/26	71/34	55/29
Borderlands 3	62/31	81/37	57/29
Far Cry 6	62/29	83/44	62/43
Flight Simulator	42/25	60/35	45/28
Forza Horizon 5	66/22	80/28	64/27
Horizon Zero Dawn	62/43	71/56	56/40
Red Dead Redemption II	70/26	86/30	61/30
Total War: Warhammer III	26/12	34/18	33/18
Watch Dogs Legion	62/22	74/26	59/20

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x 16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average frame rates at 1920x1080 medium/ultra.

SPECIFICATIONS

Architecture	Navi 24
Lithography	TSMC N6
Boost Clock	2,321MHz
GPU Cores	768
Memory	4GB 16Gb/s
TFLOPS FP32	3.6
Bandwidth	128GB/s
TBP	53W
Connectors	1x HDMI 2.1, 1x DisplayPort 1.4



This PowerColor RX 6400 has a traditional dual-slot, full-height form factor, but several cards are single-slot, half-height affairs.



Yet another innovative
Asus laptop? That'll be
the ROG Flow X16 2-in-1.

Asus ROG Flow X16

HDR done right, at last

REMEMBER THAT THING we were saying last month about Asus and world-beating laptop innovation? Well, Asus is at it again. Last time around it was the 14-inch Zenbook Pro 14 Duo OLED with its OLED tech and dual screens. This month, get a load of the new Asus ROG Flow X16, a 16-inch gaming beast that's also a two-in-one tablet, has a big old battery, an incredible mini-LED touchscreen, a monster AMD CPU, and support for Asus's ROG XG Mobile external graphics.

It feels like a full-time job keeping up with Asus's laptop output of late, let alone the rest of the industry. Anyway, let's dig into this beauty in a little more detail. It's running AMD's hot new Ryzen 9 6900HS CPU, an eight-core and 35W variant of AMD's latest mobile CPU. That's paired with a 125W version of the Nvidia GeForce RTX 3070 Ti GPU, along with a MUX switch to ensure maximum graphics performance extraction.

Factor in the 32GB of DDR5 memory, not to mention a 1TB PCIe 4.0 SSD, and you have a portable PC that's seriously up there when it comes to raw specs. Sure, there are quicker CPUs and GPUs, though not by much. Of course, there are plenty of laptops that offer high-end chips but what most of them can't compete with is the X16's screen. It's a 1440p panel with 2,560x1,440 pixels and runs at 165Hz,

which is pretty much the perfect combo for pairing with the 3070 Ti graphics—4K would be overkill in visual terms and also wallop the frame rates.

If you're thinking, hang on, plenty of laptops offer high refresh 1440p panels these days, you're right. But do they crank out 1,100 nits of brightness, support HDR 1000, deliver 100 percent coverage of DCI-P3 and pack 512 mini-LED dimming zones? In a word, no. The screen on this thing is epic—painfully bright if you want it to be, but also incredibly well calibrated.

It's one of, if not the very best full-array local dimming implementations we've seen, far better than any full-array desktop monitor. With HDR enabled, you get none of the backlighting weirdness that afflicts desktop monitors. Just eye-popping HDR performance, plus excellent SDR rendering when in HDR mode. There really are no drawbacks. You can even adjust the overall brightness level in HDR mode, something that's not usually possible with a monitor. Long story short, this is HDR done right and it's changed our minds about full-array local dimming. It can really work, after all.

From a broader performance perspective, this system is solid but not utterly spectacular. Use the optional Turbo mode in the Asus Armoury Crate app and there's little to no CPU throttling under sustained load, while gaming

frame rates are excellent but inevitably a step behind the best laptops with RTX 3080-based GPUs. Even the battery life isn't too shabby, with over six hours achievable in terms of light use such as basic web browsing or watching movies.

What's more, it's nicely built, albeit from plastic rather than premium alloys, and relatively thin and light for something so powerful. The keyboard bed is solid, which is what we've come to expect from Asus, and the trackpad is a decent size.

But surely, there's something wrong with it? The 360-degree hinge and two-in-one tablet functionality is probably engineering we could live without in return for a lower price. Ditto the ROG XG Mobile support. The Flow X16 already has a great GPU and that whole external graphics thing is niche and physically clunky in real-world usage. Those minor quibbles aside, this is a compelling portable rig if you're in the market for a 16-inch gaming laptop. —JEREMY LAIRD



Asus ROG Flow X16

GO WITH THE FLOW Absolutely stellar screen; superb all-round performance.

DOWN THE DRAIN Barely

anything if you can afford it.

\$2,700, www.asus.com

BENCHMARKS

	ZERO-POINT	
Cinebench R23 (pts)	15,746	14,773 [-6%]
3DMark Firestrike (pts)	23,131	24,192 [5%]
PCMark 10 (pts)	7,109	7,077 [0%]
Metro Exodus 1080p Ultra (fps)	79	74 [-6%]
Total War: Three Kingdoms 1080p Ultra (fps)	91	79 [-13%]
Crystal Disk read (MB/s)	6,670	6,752 [1%]
Crystal Disk write (MB/s)	4,932	4,996 [1%]
Crystal Disk 4K read (MB/s)	91	64 [-29%]
Crystal Disk 4K write (MB/s)	232	164 [-29%]
4K x265 encode (fps)	10.6	8.6fps [-19%]
Battery life (1080p video playback)	5h48m	7h8m [23%]

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our Zero Point consists of a Razer Blade 15 Advanced 2022 featuring an Intel Core i9-12900H CPU, Nvidia RTX 3080 Ti 16GB GPU, 32GB DDR5 RAM, 1TB NVMe SSD and 80Whr battery.

SPECIFICATIONS

CPU	AMD Ryzen 9 6900HS
Graphics	Nvidia RTX 3070 Ti 8GB
RAM	32GB DDR5
Screen	16-inch 2560x1440 IPS touch
Storage	1TB NVMe SSD
Ports	2x USB Type-C, USB-A 3.2, SD card, HDMI 2.0, 3.5mm audio jack, MicroSD card reader, ROG XG Mobile
Connectivity	Wi-Fi 6E, Bluetooth 5.2
Battery	90Wh
Camera	720P webcam
Weight	4.63lbs
Size	13.98 x 9.75 x 0.76-inch



The Predator XB3230K is a high-end gaming monitor, but this luxury comes at a price.

Acer Predator XB323QK

32 inches of fantastic 4K 144Hz action

THE THING WITH LUXURIES is that, once you've experienced them, it can be difficult to go back to the mundane. Whether it's fine wines, high-end hi-fi, or expensive motors, experiencing the good stuff often means that nothing else comes close. That's why this Acer Predator XB323QK 4K gaming monitor should come with a warning, lest people are tempted to spend \$2000+ trying to get a machine powerful enough to drive it.

If money's no object though, this monitor has everything going for it. It's a 4K display with an IPS panel, a huge 32-inch screen, a 144Hz refresh rate, and support for both AMD FreeSync and Nvidia G-SYNC. Those stats make it a dream monitor for gamers, offering the most premium of experiences short of an 8K television or an OLED monitor.

The Predator XB323QK also has lots of worthwhile extras and features, including two HDMI 2.1 ports, allowing you to connect both an Xbox Series X and PlayStation 5 simultaneously while taking advantage of their 4K 120Hz variable refresh rate signals. There's also a USB-C port with 65W power delivery, meaning you can connect a laptop and power it at the same time.

It also has configurable RGB lighting on the rear for that pro gamer look, built-in speakers, a headphone jack, and two USB-A ports next to its video inputs. Sadly, these are located on the underside of the body and are rather fiddly to access.

Thankfully, the monitor's performance is as impressive as its feature set. Picture quality in games is stunning thanks to a display that boasts fantastic detail and great responsiveness. Colors aren't the most vibrant, but this can be alleviated by digging into the monitor's on-screen setup and tweaking the settings. There are also preset modes available for genres such as Racing and Sports.

Gamers are also covered thanks to dual compatibility with AMD FreeSync and Nvidia G-SYNC and, combined with the 144Hz refresh rate, games driven by a suitably powerful GPU look stunning on this screen. Similarly, console owners will be able to get the best out of their machines on the Predator XB323QK thanks to the two HDMI 2.1 ports.

The screen's rated brightness of 400 nits is standard for gaming monitors and bright enough for most uses, including

work and gaming. The 90 percent DCI-P3 color space rating will be good enough for most, although content creators may want to invest in something better.

The metallic stand feels sturdy, which is important for this heavy 13.5kg monitor. The stand allows you to move the screen up and down as well as tilt it 30°, but you can also VESA mount it if you wish.

It's rare for a monitor to have built-in speakers, and though they go loud, they start to sound rather tinny at over 30 percent volume, so make sure you have some change for a decent set of speakers or headphones. Similarly, the 65W USB-C power delivery may not be sufficient to power many of the gaming laptops that will be used to drive this monitor.

The Predator XB323QK is pricey thanks to its 4K display, but it very much delivers for those looking to push their high-end GPU to the max. Support for both FreeSync and G-SYNC means it will be compatible no matter what GPU you buy in future, while a generous set of connections make this the ideal monitor for someone who uses desktops, laptops, and consoles for gaming. If you have the desk space and a beefy PC, it's a fantastic 4K gaming monitor. —GUY COCKER

VERDICT



Acer Predator XB323QK

■ **GET TO THE CHOPPA** 4K 144Hz display; USB-C and HDMI

inputs; FreeSync and G-SYNC.

■ **GET IN THE SEA** Expensive; substandard speakers; some color tweaking required.

\$1,000, www.acer.com

SPECIFICATIONS

Native resolution	4K (3840x2160)
Refresh Rate	144Hz
Panel technology	IPS
Response time	1ms
Aspect ratio	16:9
Inputs	2x HDMI 2.1, DisplayPort 1.4, USB-C
Display features	AMD FreeSync, Nvidia G-SYNC
Contrast ratio	100,000,000:1
Dimensions	71.6 x 30.9 x 53.4cm
Weight	13.5kg

HP X34

Great value ultrawide for gamers

ASK A GAMER to describe their ideal gaming monitor, and they're likely to say "4K". The problem, of course, is that driving a 4K monitor requires a high-end graphics card that can add a significant amount to your budget. For most, a realistic sweet spot is a 1440p monitor that can be driven by a more modest GPU.

HP's X34 appears to hit this sweet spot while offering lots of additional features for a reasonable price. The headline feature is its 34-inch ultrawide display with a large amount of screen real estate. It also has a high 165Hz refresh rate, supports AMD's FreeSync Premium (and unofficially Nvidia G-SYNC), and has a 1ms response time. All great things to have on a monitor under \$500.

The X34 makes a good first impression, with thin bezels along the side and top, and a small centralized base. Mounted on the included stand, the monitor is height adjustable and tiltable. It can't be rotated 90 degrees, but can be mounted on a standard VESA 100mm x 100mm bracket.

Connectivity is where things fall down slightly, with just one DisplayPort 1.4 and one HDMI 2.0 connection. That's not much if you want to hook up multiple PCs and game consoles. And while it's all good on the PC side, console gamers may have preferred the newer HDMI 2.1 standard. While the PlayStation 5's new variable refresh rate mode is supposed to require it, we found it worked fine at 1080p on this monitor, so it's not a major issue. There's also a 3.5mm headphone jack for those using wired headphones. The other big omission is there are no USB ports on this monitor, but that's probably something gamers can live without.

In terms of performance, this is a dependable monitor that delivers everything gamers need. The IPS panel offers excellent viewing angles, superb color accuracy, and great contrast, and combined with the ultrawide format, offers an immersive experience. The use of IPS also helps response times, which go as low as 1ms if you enable it in the monitor's settings. That's low, and we can report a highly responsive experience from the X34 when engaged.

HP's Eye Ease feature, which can be turned on or off, reduces high energy blue light emissions while retaining color accuracy, which helps reduce eye strain during those late-night gaming sessions.

Like nearly all gaming monitors aside from the latest OLEDs, HDR performance is nothing special, but it's there if you want to enable it in more cinematic titles.

Like the 1440p resolution, the 165Hz refresh rate sits in the sweet spot for gamers—more than fast enough for anyone except eSports players. There's support for AMD FreeSync Premium, the middle tier of AMD's variable refresh rate standards, and we also found the monitor supports G-SYNC, though it's not officially listed as such. That means this is a great option for gamers no matter what GPU they're rocking, and we enjoyed a smooth tear-free gaming experience from our RTX 3070Ti.

While the X34 is marketed primarily as a gaming monitor, content creators may also appreciate the 99 percent sRGB color space rating. Working on the X34 also feels efficient due to the ultrawide format, making this an excellent all-round desktop monitor.

There's something reassuring about a monitor that nails the basics as well as the HP X34 does. It offers all the features that most gamers need and delivers an excellent picture at a compelling price point. If you're in the market for a 1440p ultrawide, the X34 absolutely deserves a place on your shortlist. **—GUY COCKER**

VERDICT



HP X34

+ **X-CELLENT** Large 34-inch display; 165Hz FreeSync and G-SYNC; thin bezels.

- **X-TINCT** Limited video inputs; no USB ports; HDMI 2.0 rather than 2.1.

\$460, www.hp.com

SPECIFICATIONS

Native resolution	WQHD (3440x1440)
Panel technology	IPS
Response time	1ms
Aspect ratio	21:9
Inputs	HDMI 2.0, DisplayPort 1.4
Display features	AMD FreeSync Premium, G-SYNC Compatible
Contrast ratio	1000:1
Dimensions	81.65 x 5.36 x 36.81cm
Weight	8kg



© UNSPLASH



34-inches of screen
should be more than
enough for gamers.

ASUS TUF F15 2022

Value, performance and a new image for TUF?

THE TUF LINEUP from Asus is often seen as a budget-focused alternative to its ROG range. Unfortunately, this casts a negative judgment on TUF models before they've had a chance to show off what they can do. The TUF F15 has some interesting specs at a reasonable price, so does it deserve to be in the spotlight or should you opt for a premium ROG laptop?

The most noticeable difference between the TUF and ROG laptop lineups is visual. We prefer the cleaner designs offered by ROG machines, however, the F15 appears to be a step up from previous TUF laptops. As more generally budget-friendly alternatives, they often seem heavily 'gamer focused' and while it has a gamer utilitarian aesthetic, it's not too in your face. The lid features an anodized aluminum effect with a raised TUF logo. Open the lid and the laptop has a sleek appearance and, despite plenty of cheaper materials having been used throughout, it feels sturdy and rigid.

The screen features a fairly large chin bezel, but the top and sides are slim. Along the top, there's a webcam that protrudes from the lid, making it easier to open the laptop. The 720p camera is nothing special but it's clear enough for occasional video conferencing. Unfortunately, there's no physical privacy shutter, which would have been a nice touch, but a white LED indicates when the camera's in use.

The panel is where this model both shines and suffers. It's a 15.6-inch IPS QHD display with a refresh rate of 165Hz, which sounds perfect for portable gaming. Unfortunately, the color setup is more washed out than we'd like, but its saving grace is the detail offered by the 2560x1440 resolution. Paired with the 165Hz refresh rate, gaming is clear, smooth, and responsive. Of course, you can tweak color options within the system and games but straight out of the box, we were left slightly underwhelmed by the soft display. The low-profile RGB backlit keyboard has decent travel and the keys have some tactile spring to them. The WASD keys are also translucent, making it easier for you to see them in your peripheral vision. The TUF F15's trackpad is large and responsive and the buttons have a satisfying click to them, perfectly good enough for daily work-related tasks.

Our model came with a 12th Gen Intel Core i7-12700H Alder Lake chip, 16GB DDR5 RAM, and a GeForce RTX 3060 GPU inside. This is undoubtedly generous specifications for just under \$1,500. Other models offer a 3070, which would be better for gaming longevity, however, the Nvidia GeForce RTX 3060 is good enough for most gaming with settings on medium to high. The problem with our specification is that if you want as many frames as possible, it's best to run your games at 1080p, therefore you

don't get the most out of the QHD display. The FHD version with the 300Hz refresh rate makes for a more sensible option over the QHD for a more budget-friendly gaming laptop like this.

On the CPU, it's great to see a powerful 12th Gen chip here and during our testing, the laptop's performance was snappy and reliable and should last for years to come. The same goes for the newer DDR5 RAM. As far as performance goes, it ticks plenty of boxes and, at our 1080p benchmarking, achieves respectable frames of over 60 FPS at Ultra settings.

Unless you specifically want all the bells and whistles, you can save some money by choosing this Asus TUF F15 over a ROG model and still get a respectable performance with a snappy display and decent keyboard. The F15 has plenty of ports, a good battery life (when not gaming), and makes for a solid daily driver. The display needs color tweaking and some corners have been cut on both materials and the overall fit and finish, but if gaming is what you want out of a laptop, the Asus TUF F15 should be more than sufficient. **-SAM LEWIS**



VERDICT

ASUS TUF F15 2022

ALL ROUND THUMBS UP Snappy

165Hz refresh rate; sturdy build quality; good value for money.

THE BAD ATTACHED WITH THE GOOD

Washed-out display; chunky lower bezel; cheap-feeling materials.

\$1,499, www.asus.com

BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,537	1,754 (14%)
Cinebench R23 Multi-Core (Index)	10,632	12,909 (21%)
CrystalDisk QD32 Sequential Read (MB/s)	3,287	1,706 (-48%)
CrystalDisk QD32 Sequential Write (MB/s)	2,419	1,377 (-43%)
3DMark Fire Strike Extreme (Index)	24,814	99 (-100%)
Cyberpunk 2077 (fps)	68	76 (12%)
Cyberpunk 2077 RTX (fps)	18	21 (17%)
Metro Exodus (fps)	75	73 (-3%)
Metro Exodus RTX (fps)	52	47 (-10%)
Total War: Three Kingdoms (fps)	72	81 (13%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1080p zero-point consists of an AMD Ryzen 5 5600X, an XFX Speedster QICK308 Radeon RX 6600 XT, an Asus ROG Strix B550-F WiFi, 16GB of XPG Gammix D45 DDR4-3200, and a 1TB ADATA Legend 840. All games tested at 1080p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

SPECIFICATIONS

CPU	Intel i7-12700H @2.60GHz
Graphics	NVIDIA GeForce RTX 3060 6GB GDDR6
RAM	16GB DDR5 @4800Mhz
Screen	15.6in QHD (2560x1440) IPS @ 165Hz
Storage	1TB M.2 PCIe 3.0 SSD
Ports	HDMI 2.0b, Thunderbolt 4 support DisplayPort, USB 3.2 Gen 2 Type-C, 2x USB 3.2 Gen 1 Type-A, RJ45 zLAN port, 3.5mm Combo Audio Jack
Weight	4.85lbs
Size	0.8 x 9.8 x 13.9-inches



Asus' TUF range offers better value than its ROG range.

Razer Leviathan V2

The best PC soundbar just got better

THERE STILL AREN'T many soundbars available for PC gamers, but the original Razer Leviathan made an impression when it launched. It produced great sound, had lots of connectivity options, and had the usual Razer sense of style. That was eight years ago though, so it's probably time for a refresh.

The Razer Leviathan V2 makes some interesting changes, adding some key new features while dropping some previously popular ones. For example, both the soundbar and sub are larger for fuller audio, and there's now gamer-friendly Chroma RGB lighting as well as THX Spatial Audio. But we've lost the 3.5mm and optical connectivity, which limits the flexibility of this speaker for use with anything other than a PC.

The headline improvements are good news for those who care about audio quality, as the expansion of the internal space in the speaker and sub brings a big boost to sonic performance. The soundbar still fits comfortably under a monitor, but it's deeper and wider than before. The sub, meanwhile, has expanded outwards to become more of a true cube shape for more impressive bass.

The soundbar connects to a PC using USB-C, as well as a separate power cable, and a wired connection to the sub. This means it only works with a PC in its main operation, although you can connect a Bluetooth device if you want to listen to music but don't have your PC switched on.

With your PC on though, you'll be treated to an excellent aural experience, whether that's gaming, listening to music, or streaming video. The two passive radiators on the soundbar improve the depth and presence of the soundstage, while the optional feet lift the bar so it fires sound more toward your ears.

The subwoofer's size increase now makes it a more appropriate candidate for locating on the floor, whereas the previous model would sit on most desks. Your neighbors, family, or housemates might not love you for doing this though, because it does a good job of pushing out bass from its downward-firing speaker.

Razer has also added THX Spatial Audio, making the stereo mix more enveloping. It helps create atmosphere rather than precision, which helps more in movie-like games such as *The Quarry* rather than *Call of Duty*. It isn't Dolby

Atmos-quality, but it isn't priced as high as a Dolby Atmos soundbar either.

As you'd expect from a Razer product, it's designed to fit into its wider ecosystem, meaning you can sync lighting using its Synapse software. We liked that there's also a mobile app to control the soundbar, meaning you don't have to Alt-Tab out of a game to change settings.

There are some small niggles about some of Razer's design choices. The subwoofer isn't wireless, which is fine at this price, but the short lead to connect it to the main soundbar might limit your location options. The lack of optical or 3.5mm audio also limits your connectivity options if you also want to use the speaker system with a TV or games console.

The competition for the Leviathan V2 comes in the form of the recently-released Sonos Ray, which we covered in our August 2022 issue. At \$279, the Ray is slightly more expensive, but has the optical input that makes it so versatile, while it also fits into the Sonos ecosystem. But it doesn't come with a subwoofer and has no RGB lighting. If you're a pure PC gamer, we'd go for this Leviathan V2.

\$250 is a lot to spend on a PC speaker system, but the Razer is a great option. It sounds fantastic, supports virtual surround sound, and has some good audio and lighting options. —GUY COCKER

VERDICT



Razer Leviathan V2

➤ **POWERFUL** Brilliant sound; multiple connection options; great RGB lighting.

■ **MONSTROUS** Expensive; no 3.5mm or optical inputs.

\$250, www.razer.com

SPECIFICATIONS

Lighting	Razer Chroma RGB
Power	Mains power only
Frequency response	45Hz–20kHz
Connectivity	Bluetooth 5.2, USB
Surround Processing	THX Spatial Audio
Dimensions	Soundbar: 500 x 91.3 x 84mm, Subwoofer: 220 x 220 x 241.5mm
Weight	Soundbar: 1.4kg (3.08lbs) Subwoofer: 3.0kg (6.61lbs)





Big and bigger:
both the soundbar
and sub have
grown for V2.

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Logitech MX Master 3S Wireless Mouse



The best productivity mouse

IF YOU'RE A productivity whiz, then you're probably already aware of Logitech's MX Master mice series. They've carved a niche for themselves as the navigation product of choice for people who want good quality, lots of features, and loads of customization options. The MX Master 3S aims to continue this tradition by building on the success of the MX Master 3 with a brand new higher DPI sensor, quieter switches, and Logitech's new Bolt dongle which can be used across a range of the company's new wireless products.

The good news is that, by building on such a solid foundation, this remains the best productivity mouse on the market. This is an extremely comfortable mouse to have in the hand for long periods, it feels built to last, and Logitech's Flow software allows you to move seamlessly between devices and applications. This makes it highly efficient for video editors, programmers, or office workers looking to get stuff done. Sure, you're paying close to \$100 for that extra productivity, but for those who are serious about their work, that's easily a price worth paying.

So what makes this mouse so good? First of all, it's just so well made, with a luxuriously rubberized finish that's comfortable to hold for long periods, and a sturdy, made-to-last construction. It's not a small mouse so is best suited for someone with medium-to-large hands. Bear in mind that the scoop designed to rest your thumb means this mouse will also only suit right-handed people.

Controversially, the biggest change to this model of mouse is that the main click buttons have been switched from 'clicky' types to quieter models that Logitech claims are 90 percent quieter. This is great for office workers who respect their co-workers' sanity, but less so for

home workers who might have preferred the more tactile feel. On the flip side, the buttons feel like they require less force, which should help reduce finger strain over time.

The other buttons and wheels on the mouse all feel fantastic, as they did on the previous model. The electromagnetic scroll wheel can be set to freewheel or go tactile, plus there's a thumbwheel for zooming, horizontal scrolling, or a host of other customizable options. The big change in this model is the sensor, which can go from 200dpi up to 8,000dpi—double the 4,000dpi limit of its predecessor. This means the mouse is better suited to people with multiple-monitor setups, as you can navigate around with less movement. The sensor also gets bonus points for working across any surface, including glass.

VALUABLE APP

The MVP of the MX Master 3S, though, is the Logi Options+ app. If you're working across multiple computers, then it allows you to flow between them with ease. For example, I spend most of my time on a desktop PC, but I always have my work laptop next to me as well. I had the mouse connected to my desktop using the Bolt receiver and also paired to the laptop over Bluetooth, and was able to move between the two with ease, including copying and pasting text.

There's a slight catch for people running on non-Windows/Mac operating systems such as Linux, where you must manually change between connected devices using a button on the base of the mouse. This process is somewhat fiddly and cumbersome.

Battery life is excellent, rated at 70 days, meaning you only have to

remember to charge once every three months or so. The good news is that you can charge while using it, or you can just give it one minute of juice, which will be good for a few hours of use. We'd have loved Qi wireless charging, but we're glad it uses the newer USB-C standard.

Working from home over the past couple of years got us all thinking more about ergonomics, comfort, and even a little luxury in our working setup. If that's you, then the Logitech MX Master 3S Wireless mouse fits the bill. —**GUY COCKER**

VERDICT 8 Logitech MX Master 3S Wireless Mouse

■ **MASTER** Smooth and ratcheted scroll wheel; excellent software; great build quality.

■ **AMATEUR** Buttons no longer tactile; awkward thumb button; device switching button located on bottom.

\$99, www.logitech.com

SPECIFICATIONS

Wireless range	10m
Operating Systems	macOS 10.15 or later, Windows 10, 11 or later, Linux, Chrome OS
DPI range	200-8000dpi
Buttons	7 (Left/Right-click, Back/Forward, App-Switch, Wheel mode-shift, Middle click)
Battery Life	70 days
Connection type	Logi Bolt USB receiver, Bluetooth Low Energy
Dimensions	124.9 x 84.3 x 51mm
Weight	141g

Audeze Euclid

Earphones for the price of a desktop? You read that right

WE CAN'T START this review without first confronting the elephant in the room: that price tag. The words “expensive” and “audiophile” have a tight-knit relationship, so are we truly shocked by the \$1,299 cost? Audeze is well known for its high-end planar magnetic headphones and is well respected by the audiophile community. These aren't the brand's first in-ear headphones, but do the Euclids live up to Audeze's reputation?

When spending over \$1000, you'd hope that at least part of that money would go toward the unboxing experience, though sadly, it's underwhelming for the Euclids. They come in a flimsy cardboard carton that belies what lurks within. When you've gone past this cheap packaging, you are met by a clear hardshell carry case showcasing the brand's logo. We have to hand it to Audeze here because this heavy-duty case should keep the Euclids safe and sound.

They also come with a great selection of accessories and cables. In the box, you get an MMCX braided cable, a 4.4mm Pentaconn balanced cable, a Cipher Bluetooth module, a 1/4-inch TRS adapter, a mesh carry case as well as the hard-shell one, a variety of ear tips, a cleaning brush, and a clip. That's quite an assortment and demonstrates good attention to detail from Audeze that should provide you with all the gear you need to start using the Euclids.

As for the actual headphones, they are certainly an interesting piece of technology. Design-wise, they are made of black precision-milled aluminum with gold accents, including the gold Audeze logo that sits on a carbon-fiber plate on the face of the earphone. That's the premium aesthetic box well and truly checked. They do have some weight to them, which adds to the premium feel, but may not be great for long periods of use. They aren't the sleekest or most subtle in-ear headphones we have come across either. That is in part due to what hides beneath their shell. What Audeze has crammed into these is nothing short of impressive, containing 18mm single planar magnetic drivers in each earbud. Where the design falls a bit short is the red and blue indicators on the MMCX braided cable—these are to indicate

which cable connects to the left or right earphone, but it distracts a little from the premium aesthetic. A minor gripe but these aren't exactly cheap cans.

BALANCING ACT

One issue we encountered was with the first-time setup. Getting the Euclids comfortable in your ear is nothing like as simple as with Apple's AirPods, for example. Instead of the cables going straight down from your ear, they come out upward and wrap around. Though this helps with balancing the weight, it can be frustrating and makes them less quick and easy to use than other styles. It can be a problem when wearing these in public if you need to take them out to speak to someone. The problem is worse when it comes to using the Bluetooth cable, as it adds more weight to the earphones. However, when you've found the correct ear tips and fitted them correctly, they are comfortable. The Bluetooth module has a micro-USB port for charging and typical media control buttons, which are easy and quick to use.

Despite the slightly negative start to the review, we now come to the best part of the Audeze Euclids: their sound. Naturally, we had high hopes when testing earphones that cost as much as a particularly elusive GPU, but it's safe to say they live up to the Audeze reputation. One way we can tell how great an audio device performs is when the sound can transport you away from whatever you are doing, leaving just you and the music. These Euclids achieve that instantly and do a great job of blocking out background noise, delivering a super-wide soundscape.

You're immediately hit with extensive detail and sounds that you otherwise may have missed using a regular pair of earbuds or headphones. This high detail creates more focus when listening to music, resulting in a more otherworldly experience. While maintaining this precision, the Euclids also deliver punchy percussion and bass at the low ends that create a warm foundation for the sound. Piecing the overall output together



are the rich mids, which produce a well-rounded sound. Testing across a wide range of genres, the Audeze Euclids continuously deliver a rich, detailed sound, with plenty of oomph to accommodate all types of music. You can easily spend hours immersing yourself in your favorite songs and that's ideally the goal. Poor audio quality can distract from what you're listening to and that isn't the case here. There is certainly an audiophile market for in-ear devices that cost this much, it's just whether you can justify the price to carve out your own corner of audio heaven. —SAM LEWIS

VERDICT

9

Audeze Euclid

AUDIO BLISS Rich, detailed and fully immersive sound; high-end build quality.

AUDIO MISS Wallet-rinsing; awkward setup; subjective looks.

\$1,299, www.audeze.com

SPECIFICATIONS

Driver Type	18mm planar magnetic driver with neodymium N50 magnet
Frequency Response	10-50,000Hz
Impedance	12 ohms
Connectivity	Auxiliary, Bluetooth 5.1
Compatibility	PC, mobile
Design Style	In-ear, closed-back
Weight	0.031lb without cable

Corsair HS65 Surround

A good value daily gaming headset?

THE HS65 SURROUND is the cheapest of three newly-released Corsair headsets. Corsair has proven over the years that it knows how to put together a solid gaming headset, but how does this \$80 offering sit in its line-up? Could the HS65 be your main gaming companion or should you opt for a more expensive option?

Picking it up for the first time, the HS65 certainly feels more expensive than the price tag may imply. Although it's a mainly plastic construction, it's soft to the touch and contrasts well with the other materials used. We're reviewing the white version and if we had to choose, we'd opt for this over the carbon black alternative. The white with gray accents looks more premium in our eyes. Talking of the gray accents, these make an appearance on the earcups and headband cushions, which are extremely plush thanks to the memory foam used, making them comfortable for long periods of time. Corsair's headsets are consistently nice to wear, and the HS65 Surround doesn't spoil that reputation.

The earcups have plenty of swivel and adjustment, and although they're a light pair of cans, they feel sturdy enough to be worn daily, either at your desk or on the go. They also feature a metal grille on each cup that houses the Corsair logo, adding to the premium aesthetic of this headset. There are no features on the right earcup; it's on the left side where you can find the 3.5mm auxiliary cable and volume dial.

There's also an omnidirectional microphone that becomes active when moved down from its vertical position. It's easy to use and bends so you can get the perfect angle when in a party chat. In the box, you also get a Dolby 7.1 Surround USB adapter for hooking the headset up to your PC. To get the most out of the HS65 Surround, use this instead of just plugging in the 3.5mm auxiliary cable.

As the cheapest option in the new line-up, there aren't too many features on offer. No Bluetooth or wireless connectivity, and no playback controls or RGB lighting. On the flip side, this adds to

the device's ease of use. There is no fear that your headset will run out of charge; it's a simple plug-and-play device that just works. One thing we would have liked to see is a detachable cable, so you could replace it if it breaks—we've all trapped a cable and broken it at some point. So, for the money, you're getting a straight-to-the-point headset with premium design and build quality, but how does it sound and what's it like in gaming situations?

In short, it follows the majority of Corsair's gaming headsets—games sound punchy and immersive, especially when using the Dolby USB Surround adapter. It's crucial in competitive games to have accurate directional audio and the HS65 Surround delivers. The bass is rather heavy and can be overwhelming in some areas, but you can tweak this within the iCUE software, which is now integrated with SoundID from Sonarworks. This tuning software enables you to create audio profiles for different users or scenarios.

Software aside, the mids and highs can start to feel muddy at higher volumes and the overall sound stage becomes a little flat when listening to music loud. However, for the most part in gaming, it's a well-rounded pair of headphones that perform strongly in high-octane head-to-heads, casual RPG titles, and even occasional music listening. The Discord-certified microphone is also worth a mention because it picks up your voice clearly without grabbing too much of your background noise. Again, it's easy to use because you just fold it down to go live, which is how we like it—nice and simple.



At under \$100, the Corsair HS65 Surround ticks plenty of boxes but also leaves some unchecked. The lack of wireless connectivity could be enough to turn many people off, but those who still prefer the ease and dependability of a wired option shouldn't overlook this headset. The HS65 feels, looks, and sounds more expensive than it is, and has a sturdy build quality and a crisp mic. Whether you're using it for gaming or taking video calls in the office, it's a great value headset. —SAM LEWIS

VERDICT

8

Corsair HS65 Surround

IN THE MIX Strong software support; premium aesthetic;

immersive surround sound audio; low price tag; clear microphone.

OUT THE MIX Lacks a lot of features; non-detachable cable.

\$80, www.corsair.com

SPECIFICATIONS

Driver Type	50mm neodymium
Frequency Response	20-20,000Hz
Impedance	32 ohms
Connectivity	3.5mm auxiliary, auxiliary-to-USB adapter
Compatibility	PC, Mac, PS4, PS5, Nintendo Switch, mobile
Design Style	Closed-back
Weight	0.62lbs

Long-range combat is a staple of the series, but this game often brings things closer.



THIRD-PERSON
TACTICAL
SHOOTER

Sniper Elite 5

Rebellion has *Enemy at the Gates* in its sights

PRACTICALLY OUR FIRST SHOT in *Sniper Elite 5* goes through a luckless enemy soldier's testicles. We were aiming for his head, but that doesn't really matter right now. The WWII stealth-action series has long been known for its gory X-ray camera, a 'reward' for a nicely placed shot that shows the bullet smashing its way through skin and bone on its way out the other side. But we didn't expect so many all at once.

They were set up for it, of course. Those soldiers manning the searchlights that night didn't stand a chance, and neither do their compatriots who stand on ledges just asking to be pulled over, or investigate strange whistles coming from tall grass with not a thought for their personal safety. Having taken us around northern Africa and Italy in the past two installments, *Sniper Elite* arrives in France just in time for D-Day.

Every game from *Call of Duty* to *Company of Heroes* has taken us through the Normandy invasion, but *Sniper Elite* returns to the overused setting to wring new perspectives and stories out of it. It's successful in this endeavor, and the game finds a new confidence and inventiveness in levels that should be familiar to us all by now. Fields, the approaches to villages

containing German high command, hedgerows surrounding bunkers and radar installations, they're all here, but something's different.

Possibly, it's because the game no longer prioritizes sniping quite so much. The X-ray camera now triggers when you kill with knives and pistols, and the amount of time your rifle spends slung across your back is increased. A level set on a tiny island, completely dominated by a single town, and reachable only by a narrow causeway is an absolute standout in this regard. All narrow streets and steep gradients, it seems to have been deliberately designed as the worst possible place to infiltrate while carrying loud, long-range weaponry.

Happily, protagonist Fairburne has other skills and there seems to be a handy uptick in the supply of suppressed weaponry, too. Subsonic or even wooden bullets allow for a quieter approach, even a non-lethal one, while the familiar drone of aero engines (or the clatter and bang of a sabotaged generator) supply just enough cover for a shot if you time it right. Miss, and it's cat and mouse among the houses, a mass of automatic weapons against your retreating back, the constant threat of other snipers about to put a hole

in you from half a mile away weighing on your mind.

Unlike in the bunkers, where pulling your submachine gun from your back and using doorways for cover, occasionally pelting your enemies with their own grenades, is a worthwhile tactic, you don't get very far in the open streets unless you take a more circumspect approach. The way the game now requires you to adapt your tactics based on circumstances and location, yet still gives you ample opportunity to silently kill with the huge amount of equipment Fairburne carries around, is to its eternal credit.

A different, more open, level gives you the opportunity to go nuts with a rocket launcher, a one-man tank-killing machine, while the enemy guards must rank among the genre's most artificially stupid, investigating noises alone and taking no notice of colleagues who suddenly disappear unless they find an actual body. Linger your sights over a bad guy gives you a little information about his life and hobbies, as well as usefully tagging him, and makes even this phase of the conflict more interesting.

There's an upgrade system at work throughout the game, opening up new skills and increasing things such as



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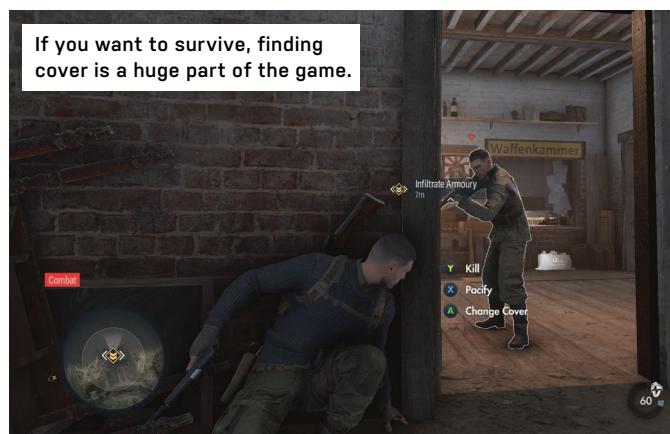
Pulling unaware enemies over ledges is always amusing.



Gory kill-cams like this can be switched off in the options.



Unlocking or discovering new sights and gun parts increases your lethality.



If you want to survive, finding cover is a huge part of the game.

your health bar as you gain experience through kills. The perks mean it's a little easier to move through the world without fundamentally changing it, making the new focus on close combat more palatable in a game about sniping. Long-range encounters are still breathtaking, however, allowing for wind and bullet drop to remove the skull of a high-ranking enemy before slipping away.

We're not sure what the *Sniper Elite* devs have been playing to give them such inspiration for the positive changes, but we want some of it, too. Actually, one thing they have been playing is *Elden Ring*, or possibly *Deathloop*, as it's now possible for your game to be invaded by a hostile sniper, a Jager, controlled by another player. It's a great fit for the formula, adding tense

games of cat and mouse to an already tense game of cat and many mice, but location updates mean you know roughly where the other one is all the time, so any attempt to camp and lie in wait is just as likely to be greeted with a grenade skipping over a low wall toward you as it is a counter-sniper bullet through cover.

The rest of the game melts away as you stalk your human prey, with the ability to return to your most recent save once it's over and carry on with your campaign mission from wherever you happen to be or even go for a rematch with the same Jager—just one of the intelligent ways Rebellion has approached the matter of multiplayer in a single-player genre (there are, of course, other standard multiplayer modes, but none is so interesting as the invasions). You can turn the whole Jager experience off, should you prefer to keep cracking AI heads unmolested instead.

It's not a perfect game—there are some dull levels, the plot is hokum, and it can be frustrating to be chased to your death for the fifth time by a bunch of goons who should have been at your mercy—but what stands out about *Sniper Elite 5* is how it continues the upward trajectory from the previous installment in the series, and even from 2012, when

Sniper Elite V2 introduced the X-ray cam. Environments are detailed and so full of extra routes and shortcuts that you'd be forgiven for thinking they were designed by Arkane. You can play the whole thing, including defending against Jager invasions, in co-op. Or you can become the Jager, suddenly finding the whole of a level's AI machinery on your side, rather than something to be destroyed.

Sniper Elite is now a more rounded game than ever, but this can take away from the fact it's meant to be a game about sniping. However, being a one-man army in the face of the German occupation of Europe is a videogame staple, and if you're going to attack one of those in 2022, this is surely the way to do it. —IAN EVENDEN



VERDICT
8

Sniper Elite 5
SNIPING A grisly but exciting journey across Europe—and through plenty of Europeans.
SLIPPING No longer so much about sniping; still contains some dud levels.
RECOMMENDED SPECS Core i5-8400 or equivalent; 16GB RAM; DirectX 12-capable GPU with 6GB VRAM.
 \$50, <https://sniperelite.com>, Rated: M



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① Storage

✓ 6GB

① Google Analytics integration

✓ Included

① WordPress plugins

Be able to add forms, calendar, and more.

✗ Not included

✓ Unlimited plugins

WordPress vs. Wix

Which website-building platform should you use?

PUBLISHING A PERSONAL website was once costly and complicated. But not any longer. User-friendly platforms such as WordPress and Wix enable you to publish online for free—you might not even need to pay for hosting. They give you everything you need to design and populate your site, maintain it, and interact with visitors. It's estimated that nearly half a billion sites are built on WordPress, while upward of 200 million people use Wix.

If you want to get started for free, WordPress enables you to host a site as a subdomain of WordPress.com, which means you don't need to worry about configuring databases or keeping your site up to date. The downside is that by default your site lives within a subdomain, such as <http://mysite.wordpress.com>. If you want your own domain to point to a WordPress.com-hosted site, you need to pay \$48 per year (or \$4 per month) for the Personal plan; this also lets you remove WordPress.com ads, collect payments, perform basic design customization, and benefit from unlimited email support.

If you already have a domain, you can run WordPress there. Many web hosts offer one-click deployment of WordPress, and can take care of tracking and installing

updates to the WordPress software, along with any themes and extensions you've installed. If your host doesn't offer this, you can upload and configure WordPress yourself. All you need is a server running PHP 7.4 or later, plus either MySQL 5.7 or later, or MariaDB 10.2 or later, which few hosts will have trouble with.

Wix also offers free hosting, though you end up with a more complicated address. It uses both a subdomain based on your username, and a directory based on your site name. So, if your username is "myusername" and your site is "mysite," your "about" page is located at <http://myusername.wixsite.com/mysite/about>.

Although you can't download the Wix source code and host it on your own domain, you can use your own domain name; this costs \$16 a month and gets you 2GB of storage and 24/7 customer care. If your only aim is to use your own domain, that's considerably more than the \$4 per month WordPress wants.

If you opt to host your site at WordPress.com, you're walked through a three-stage process that involves providing your email address, choosing a domain (whether a free subdomain or paid commercial domain), and opting for a plan—the link

to "start with a free site" is discreetly displayed at the top of the page, above the more conspicuous charged-for options.

GOING LIVE

You can then start designing your site or creating an online store if you've signed up for a paid plan. Your first job is to choose a theme; plenty of suggested templates are shown, and you can preview what each one will look like when live. As soon as you've picked one, you're presented with a live placeholder site that you can edit and publish. When you're happy, just click through a few pages and your site is live.

The process with Wix is similar. The site walks you through a series of screens that help you define the goals of your site, then integrate features such as blog pages, chat, and forms. More ambitious tools are available, too, such as music streaming, the ability to take food orders, and sell memberships. Be warned—it may not be obvious, but some of the features offered need to be paid for.

Once you've chosen your elements, you can start building your site using the Wix Editor, which offers large thumbnails and full-screen previews to give you a clear impression of what the finished product

Wix Premium Plans

Wix gives you 100s of templates, unlimited pages & top grade hosting FREE. Upgrade to Premium and get even more.

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As with WordPress, you need to pay to get some of the truly useful features on Wix, such as removing ads from your website.

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Essential for accepting online payments

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Custom solutions tailored to your brand

		VIP First Priority Support	Pro Complete Online Branding	Unlimited Entrepreneurs & Freelancers	Combo For Personal Use
		\$45 /month	\$27 /month	\$22 /month	\$16 /month
Custom domain	①	✓	✓	✓	✓
Free domain for 1 year	①	✓	✓	✓	✓
Remove Wix ads	①	✓	✓	✓	✓
Free SSL certificate	①	✓	✓	✓	✓
Storage space	①	100 GB	50 GB	5 GB	2 GB
Video hours	①	5 hours	2 hours	1 hour	30 minutes
Ad vouchers	①	✓	✓	✓	—

will look like. Alternatively, you can take advantage of the new Wix ADI, which uses AI to come up with an appropriate design.

Both WordPress and Wix offer dashboards featuring a wide range of tools for managing, maintaining, and monitoring your site, but their approaches are different. WordPress distinguishes between ‘pages’—the permanent fixtures such as ‘about’ and ‘contact’ pages—and posts, which are more immediate and analogous to blog entries.

The two platforms both let you go beyond the basics by extending their core features. The Wix App Market is neatly categorized and easily searched, with a full description of every app. There’s plenty of free content, but also a fair number of commercial add-ons, which don’t always have a free tier or trial. A busy reviews system enables users to share their views and allows developers to respond to comments.

When you add an app to your site, Wix warns you which aspects of your code and content it will have access to; once integrated, an app has similar controls to the rest of the editing interface, so it can easily be repositioned by dragging and tweaked using floating control panels.

WordPress also offers a mix of free and paid-for plugins through the dashboard. However, if you host your site at WordPress.com, all plugins require a Pro subscription at \$15 per month, even for those paying for a Personal plan. For self-

hosting, no such restriction applies. You can install plugins from the dashboard or upload them to your server manually. As with the Wix App Store, there’s an active community of users rating plugins in the catalog, which can be handy because there are often multiple options that do similar things.

WordPress offers apps for iOS and Android, which let you access and manage multiple sites on the go. You can upload images from your phone, write posts or pages, and track your access statistics. There are matching desktop apps for Windows, macOS, and Linux.

Not everyone is in a position to run their own site, of course. If you’re looking for a hosted solution, WordPress.com may at first look like the obvious choice, as it’s free. However, the fact that you can’t install plugins without an expensive subscription means it could well hold you back once you want to develop your site.

It’s worth noting that Wix isn’t ideally suited to big projects. Officially, Wix sites are capped at 100 pages, and even if you’re within that, Wix warns that adding pages can affect loading time and performance. There are workarounds, such as building dynamic pages that draw content out of a database but, by design, WordPress is better suited to managing large sites.

Clearly, your choice of site platform is nuanced. If you want to self-host, WordPress is your only option, and it promises easier options for future

growth. However, for a slick all-around experience, Wix shines. The interface is attractive and easy to use, making it a stronger choice for less experienced users or anyone who feels comfortable using page layout software for print.

In the end, you do need to make a decision—once you’ve built a site in Wix or WordPress, there’s no simple way to migrate it to the other platform. However, as they both offer free accounts, you can test the waters by trying out the tools and features on offer, and optionally upgrade to a paid-for service once you’re ready to make a commitment. —GUY COCKER

VERDICT
9

WordPress
WORD UP Free to set up; versatile; easy to export to another provider.
MUM’S THE WORD Less easy to use than Wix; may require some technical knowledge.
WordPress Free \$free, WordPress Plus \$4/month, www.wordpress.com

VERDICT
8

Wix
WIX Simple interface; easy to set up any type of website; AI designer.
WACK More expensive than WordPress; fewer advanced features; 100-page limit.
Wix Combo \$16/month, Wix Unlimited \$22/month, Wix Pro \$27/month, www.wix.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

- > Apple Affection
- > Gift Guides
- > Linux on Blueprints

More bites of the Apple

I know that what I'm about to say is sacrilege but, frankly, the PC fanboys can get off my back about it. Basically, I love how awesome Apple's integrated ecosystem has become, and I'd love to see more coverage of it in *Maximum PC*. I have an iPhone, iPad, Macbook, and AirPods, and as the old Apple marketing tagline goes, they simply just work.

Don't get me wrong, I still love my custom built PC. It's my favorite non-lifestyle thing in the world, for sure, but I don't treat it like a tool—it's a hobby, something I'm always improving, upgrading, and investing in. However, Apple devices are different, I see them as tools.

Apple devices are exceptionally high quality and work well for general productivity and media consumption on levels that Windows just can't compete with. Windows is constantly getting better at syncing with Android, but Microsoft doesn't have it down to a tee like Apple, thanks to its closed ecosystem. I can feel the PC nerds breathing down my neck as I speak...

Take my AirPods. Sure, I could have gotten some nice Bose noise-cancellation headphones for a similar price as the AirPods Pro, but would they sync across my devices with virtually no setup process? I don't think so! I would have a nice life of constant Bluetooth fiddling, based on previous experience.

The point is, Apple has had me trapped in its world for a long time now and I have no intention of going back. When I need to get stuff done, I can put aside my technical nerdy side and just get stuff done. And yes, they have their issues, but Apple computers are PCs too! —G. Jones

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: First of all, thank you for braving the potential backlash to put your thoughts down about the benefits of living the Apple life. I like to think that we're all polite enough to hear differing opinions without getting upset about it, such as when we did our Mac vs. PC feature in the April 2022 issue—the Mac came out on top in several

areas and I didn't receive any threats of violence at all!

I joke, but I think the tech market is so big and so influential these days that there's enough room for lots of different types of people, most of whom get along just fine. On a personal level, before the pandemic, I was an Apple fanboy, similar to yourself. I owned a Macbook, an iPhone, and an iPad, and had a PC desktop for gaming.

However, my personal circumstances changed and I bought a gaming laptop—a decision that led me to fully extract myself from the Apple ecosystem. It was a painful, manual process of exporting Notes, Reminders, and Music playlists across to other systems, but after a few days, I got out and never looked back. Now I'm at the point where using my work Macbook and iPad to check over pages of this magazine sometimes feels strange because I've become so accustomed to Windows and Android.

That said, I totally appreciate the benefits of the Apple ecosystem,

mainly for the reasons you give in your letter. Changing Bluetooth devices is fiddly and sometimes doesn't work. Content I thought I'd downloaded on Netflix and Ready often isn't there when I want it. Instagram pictures are sometimes posted upside-down for no apparent reason. But I wouldn't change it because I love the flexibility and value I get from being out of the Apple ecosystem.

Many of our tutorials, features, and reviews should still appeal to Apple users as much as PC fans, so hopefully, you still enjoy the magazine. And we've been blown away by how Apple's latest processors have performed. How many of you out there are Apple users? Let me know at editor@maximumpc.com.

Christmas Wishes

I've been a *Maximum PC* reader for a long time, and one feature I miss is the annual holiday issue where the staff make geek gift suggestions. I don't need the stockings by the fire backdrops, and staff dressed as elves, but there were usually a few things

submit your questions to: editor@maximumpc.com

I hadn't thought of that I could suggest for my family when it came to the big day.

Gift giving around that time of year is popular with many cultures and religions, and could also include year-end suggestions for upcoming birthdays. Maybe if each staff member chimed in with a wish for an extravagant gift (\$1000-\$2000), a moderate gift (\$200-\$300), and stocking stuffers (under \$20) from their own wish list of geek-oriented, not necessarily computer-driven, ideas. I know the price ranges are relative, but you review gear and always comment about whether something is expensive or reasonable.

I'd love to see how creative and helpful the staff could be!

—P. Chapman

**EDITOR-IN-CHIEF,
GUY COCKER, RESPONDS:**

Well there goes my elaborate months-long plan to get the *Maximum PC* team dressed up as elves for a Christmas Gift Guide photoshoot. And just after I'd secured the photography budget!

I think this is a great idea, and even though as I write this I'm suffering in the sweltering summer heat, magazine lead times being what they are, it will soon be time to start thinking about Christmas coverage. If a new generation of graphics cards makes it out in time for the holiday season then we'll have no trouble filling the extravagant \$1,000+ price point you mentioned in your letter. But there are loads of other options that spring to mind—if Santa is reading this, then the \$1,299 Alienware OLED monitor we reviewed in our June 2022 issue will be top of my list this year!

But Christmas is also a time when loved ones can treat you to something special without splashing

out. It could be that mouse that transforms your game of *Apex Legends*, a stylus that will allow designers to try out new projects, or some headphones that make working from home more bearable. Thanks again for the idea, and watch this space as we head towards the holiday season.

Longing for Linux

My friends and I are huge fans of your magazine. It provides us with plenty of things to discuss because all of us have differences in the aspects of PC life that we enjoy.

I'm writing because I have a couple of questions and requests. I haven't seen much on the Raspberry Pi as of late. Is there a reason for this?

I also really enjoy the three-level system builds in the back of the magazine each month. With the current state of Linux, is it a viable option for the OS on the mid-range and turbo builds? OpenOffice has been available for years for Windows, as has GIMP.

Are there any options for programs similar to Quicken, QuickBooks, Password Managers, antivirus, or live streaming on Linux?

With Windows now having a Linux kernel, I would like to see something about running Linux programs on Windows. I would also like some information on Linux-based, business-focused programs.

Once again, I'm a big fan and am enjoying your tenure so far. Keep up the great work! —C. Mitchell

**EDITOR-IN-CHIEF,
GUY COCKER, RESPONDS:**

Thanks for your kind words and the compliments on the magazine.

If you're looking for something Raspberry Pi-flavored, then check out our August 2022 issue,

where we go in-depth on using just such a machine to power a media center for your living room. It's a lot cheaper than buying something like the Nvidia Shield, plus you can add all sorts of cool extras, such as lighting that responds to what's happening on screen to really add to the cinematic experience. I hope you like it.

In terms of using our Blueprints as Linux-based machines, there's absolutely nothing stopping you. We suggest Windows as the OS purely because we assume most of our readers will be interested in playing games and/or running Windows-based creative apps on their machines. However, if you don't need those, then Linux makes sense as an alternative.

In terms of Linux-based alternatives to the software you asked about, I would suggest the following: Quicken = GnuCash, Quickbooks = Wave, Password Manager = Bitwarden, Antivirus = Sophos, live streaming = OBS Studio. If you're looking for more alternatives, then I suggest www.alternativeto.net, which lists the platform compatibility for major software applications, and suggests alternatives for other operating systems, many of which may be free.

As you say, running Linux programs on Windows is a new feature for Microsoft's OS, and while we've mentioned it frequently in these pages, we haven't yet done a guide or a feature on it. I've passed your comments onto Nick Peers, who has been doing our Windows 11 tips and tricks series for the past few months, to get his thoughts.

Privacy Invasion

Your article on how the FBI searches citizens' data can only be seen

as inflammatory and needlessly provoking fears of the 'good guys'. Every day, we hear about large corporations misusing our 'personal' information and how we should be worried about that, but we never hear about foreign intrusions into the very same data.

The way I see it, the FBI is only one of many players invading our 'privacy space' for presumably national defense reasons. Why should we restrain our own agencies from looking at the same data that foreign countries most likely have access to?

Shouldn't you have mentioned this?

—C. Sugden

**EDITOR-IN-CHIEF,
GUY COCKER, RESPONDS:**

Our news writer Chris regularly submits stories on privacy, some of which relate to the government and some of which relate to the private sector. Apologies if this story came across as unbalanced—there are many nefarious agents out there, but we are often limited by word counts in our news stories.

Either way, I think it's a good reminder to make sure your data and internet use are as secure as possible. I use a VPN, encrypt my files, and store digital currencies in a cold storage wallet, but I mainly use Windows rather than Linux, dip in and out of public networks regularly, and have data spread all over on a plethora of drives and servers.

I will discuss a proper deep-dive into online security for a feature in an upcoming issue. I get the feeling the rest of the year will be dominated by new PC hardware coming our way, but data security is always an important topic and one I'm sure other readers are also keen to learn more about. ☺

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET



AFTER A RECENT OVERHAUL, our budget Intel build sees only two changes to its lineup this issue. A change in price on the previous Seagate Constellation ES 7200 HDD meant that we exchanged it for the Seagate ST4000NM0024 on both builds. With the same 7200rpm and 4TB of capacity, it is a close match but it has a \$20

hike over the price from the previous issue. There's a \$5 increase on the 500GB MSI Spatium M450 SSD, which now features in both PCs—it's not an ideal start, but both are solid components.

The G.Skill Ripjaws V sticks marginally rise in price too, but thankfully, there is one price difference on the Intel budget machine that works in our favor—a \$20 drop from the previous \$140 price tag on the ASRock B660 Pro RS mobo. This LGA1700 board is a great pick-up at this price. Our Gigabyte Eagle OC has stayed at the same \$330 mark, which is a pleasant surprise—we're as shocked as you are to see steady GPU prices!

On team AMD, there are a few more changes than on the Intel side. The biggest is the switch from our previous MSI Mech Radeon RX 6600 XT to Gigabyte's Radeon RX 6650 XT EAGLE card. Just \$4 cheaper, it makes more sense to opt for the newer and more efficient card that's still in stock. We also get a welcome drop in the price of our CPU. At Walmart, the AMD Ryzen 5 5600X is now around \$35 cheaper than before. It's a brilliant budget CPU, so how can we complain?

Other than the change from Seagate Constellation ES to the ST4000NM0024 and the upgrade to the 6650XT graphics card, the AMD machine remains the same. We keep the 16GB Corsair Vengeance LPX CL16 @ 3600MHz. There is a price drop of \$5 this time around, but a small win is still a win. Nothing changes on the motherboard, it still works well in this build, piecing all the components together. More importantly, it remains at the same low price point.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	\$95	
PSU	550W Asus TUF Gaming 80+ Bronze	\$50	
Mobo	Gigabyte B550 Aorus Elite AM4	\$125	
CPU	AMD Ryzen 5 5600X	\$175	
GPU	Gigabyte Radeon RX 6650 XT EAGLE 8GB NEW	\$375	\$375
RAM	16GB (2 x 8GB) Corsair Vengeance LPX CL16 @ 3600MHz	\$73	
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD	\$60	
HDD	4TB Seagate ST4000NM0024 7200 HDD NEW	\$67	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$1,052 / \$1,052

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	\$95	
PSU	550W XPG Pylon 80+ Bronze	\$60	
Mobo	ASRock B660 Pro RS LGA 1700	\$120	
CPU	Intel Core i5-12600	\$230	
GPU	Gigabyte Eagle OC GeForce RTX 3060 8GB	\$330	\$330
RAM	16GB (2 x 8GB) G.Skill Ripjaws V CL16 @ 3600MHz	\$75	
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD NEW	\$60	
HDD	4TB Seagate ST4000NM0024 7200 HDD NEW	\$67	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$1,069 / \$1,069



MID-RANGE

ALTHOUGH THE AMD mid-range build only sees the same HDD change we had for the budget machines and a change in CPU coolers, there are shifts in prices across the board. Our Lian Li PC-O11 case has been reduced by \$4 but that's canceled out by the EVGA SuperNOVA going up by \$5. This 750W PSU is currently

identically priced to the GA variant seen in the Intel mid-range build and has an equal 80+ Gold rating. One of the main price changes is on our ASRock Radeon RX 6800 XT Phantom Gaming D. It has gone up by around \$50 but is still one of the best cards to have in our AMD mid-range PC. The AMD Ryzen 7 5800X falls by \$11 and is now cooled by a different CPU cooler, the Cooler Master MASTERLIQUID ML240L RGB V2. This finds its way into the Intel machine too, as the Enermax Aquafusion 240 ARGB is no longer available at its sale price of \$60.

For the rest of the Intel machine, we've swapped out the Asus TUF Gaming GeForce RTX 3070 8GB with an MSI VENTUS 2X OC GeForce RTX 3070 8GB. Not only is it \$20 cheaper, but this 8GB GPU is also now priced similar to RTX 3070 LHR cards, so is a more sensible choice. Both our GPUs are in stock, which means you can avoid the hefty street prices. Other than this GPU change, both mid-range builds receive the same changes with the Cooler Master MASTERLIQUID ML240L RGB V2 and the 4TB Seagate ST4000NM0024 entering the picture.

We stick with the more powerful Z690 chipset in our ASRock Pro RS and keep the Intel Core i7-12700F paired with it—prices for this powerful duo remain the same. We save \$22 on the (2x 16GB) Corsair Vengeance RGB RT CL16 RAM and a further \$10 on our Corsair MP600 Pro LPX SSD. For \$80, this 500GB solid-state drive is a powerful storage solution. With prices altering slightly across most components, the overall totals remain similar to last time. We're just relieved they're no longer skyrocketing.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	\$150	
PSU	750W EVGA SuperNOVA 750 GT 80+ Gold	\$80	
Mobo	ASRock X570 Steel Legend AM4	\$145	
CPU	AMD Ryzen 7 5800X	\$298	
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2 NEW	\$80	
GPU	ASRock Radeon RX 6800 XT Phantom Gaming D 16GB	\$695	\$695
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz	\$138	
SSD	500GB WD Black SN850 NVME M.2 PCIe 4.0 SSD	\$85	
HDD	TB Seagate ST4000NM0024 7200 NEW	\$67	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$1,770 / \$1,770

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	\$150	
PSU	750W EVGA SuperNOVA 750 GA 80+ Gold	\$80	
Mobo	ASRock Z690 Pro RS LGA 1700	\$190	
CPU	Intel Core i7-12700F	\$313	
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2 NEW	\$80	
GPU	MSI VENTUS 2X OC GeForce RTX 3070 8GB NEW	\$580	\$580
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz	\$138	
SSD	500GB Corsair MP600 Pro LPX M.2 PCIe 4.0	\$80	
HDD	TB Seagate ST4000NM0024 7200 NEW	\$67	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$1,710 / \$1,710



WITH OUR TURBO BUILD, we have some interesting alterations, mainly for the Intel rig. On the AMD PC, our newly added ASRock X570 Taichi AM4 motherboard saves us \$76 from the last issue. Although these turbo builds are more focused on performance over cost savings, we can't help but enjoy it when a component

goes down in price by this much. Continuing the good run, the EVGA SuperNova P6 80+ Platinum power supply is \$11 cheaper and the recently added CoolerMaster MasterLiquid ML360 Illusion 360mm is down by \$5. Again, we're glad that the GPU prices have hardly altered, and while it'd be nice to see some larger price reductions, we will take anything we can. The same ASRock OC Formula Radeon RX 6950 XT remains and offers excellent performance with overclocking potential.

There have been some substantial changes this time for the Intel turbo machine. Our mighty Corsair HX850 80+ Platinum rises by \$5 and the 6TB WD Blue 5400 HDD has risen by \$15 too. Both builds have been hit by a small increase as they contain the same HDD, but there's better news elsewhere as we are happy to see that the Intel i9-12900K is now \$560 rather than the previous \$599. This lightning-quick processor is perfect for gaming with its hybrid architecture and simple one-click overclocking feature. We will take a \$40 decrease on this chip all day long.

The 12900K now sits on a different motherboard from last time, an Asus TUF Gaming Z690-Plus WIFI. Sitting under the \$300 motherboard price cap, it has the all-important Z690 chip and DDR5 support, and saves us \$23. One of the most pleasing changes we have made is the switch from an RTX 3090 to a Ti variant, specifically the MSI GeForce RTX 3090 Ti Gaming X Trio 24GB. With no stock issues and costing \$30 less than the Gigabyte GeForce RTX 3090, it was a no-brainer. We've also paired this with some slightly faster and cheaper RAM. The G.Skill Ripjaws S5 sticks run at 5600MHz compared with the 5200MHz speeds of the Corsair Vengeance sticks before them.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	\$190	
PSU	850W EVGA SuperNova P6 80+ Platinum	\$159	
Mobo	ASRock X570 Taichi AM4	\$224	
CPU	AMD Ryzen 9 5950X	\$549	
Cooler	CoolerMaster MasterLiquid ML360 Illusion 360mm	\$158	
GPU	ASRock Radeon RX 6900 XT Phantom Gaming D 16GB	\$1,099	\$1,099
RAM	64GB (2 x 32GB) G.Skill Trident Z RGB DDR4 @ 4000MHz CL18 NEW	\$340	
SSD	1TB WD Black SN850 M.2 PCIe 4.0	\$136	
HDD	6TB WD Blue 5400 HDD	\$95	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$2,982 / \$2,982

INTEL INGREDIENTS

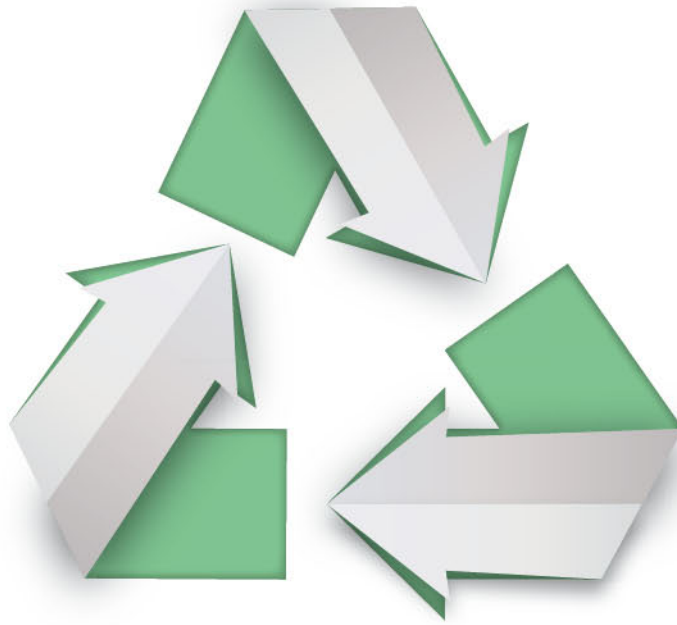
PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	\$190	
PSU	850W Corsair HX850 80+ Platinum	\$175	
Mobo	Asus TUF Gaming Z690-Plus WIFI DDR5 LGA 1700 NEW	\$273	
CPU	Intel Core i9-12900K	\$560	
Cooler	MSI MAG CORELIQUID C 78.73 360mm NEW	\$145	
GPU	MSI GeForce RTX 3090 Ti Gaming GAMING X TRIO 24GB NEW	\$1,470	\$1,470
RAM	64GB (2 x 32GB) G.Skill Ripjaws S5 DDR5 @ 5600MHz NEW	\$450	
SSD	1TB Gammix Gaming S70 M.2 PCIe 4.0 SSD	\$117	
HDD	6TB WD Blue 5400 HDD	\$95	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	\$32	

Approximate Price: \$3,507 / \$3,507

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